A Guide to the Construction and Management of Community Gravel Beds

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Community Gravel Bed for the City of Robbinsdale, MN. Photo credit: S. Papiz.

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Part 1: Introduction and FAQs

(Optional for those with gravel bed experience)

What is a community gravel bed? That term does not intuitively conjure up an accurate image of what it actually is. If you are thinking it sounds like a pile of rocks…in a community…then you are normal. A community gravel bed (CGB) does have rocks and it is located for a "community" to use, but it is a bit more than that (fortunately).

The vision a normal person might have of a community gravel bed.

A CGB is a temporary holding area for purchased trees and shrubs, specifically ones that have been purchased with no soil around their roots (aka, bare-rooted). It can also be used as a "root system recovery facility" for those wayward root systems that have lost their way and purpose (aka, "pot-bound" root systems).

Although some commercial tree nurseries do use gravel beds as growing areas, the sole intent for this guide is to provide a temporary holding area for trees and shrubs that will be planted within a few to many weeks by the community or group.

A CGB can take on a variety of shapes and sizes, and can last from a few weeks to a few years. They can be as simple as a pile of gravel on an old parking lot, a plastic wading pool, or a constructed feature made of concrete or wood. There are a lot of

Trees for Gravel Beds:

Bare-rooted trees:

And Pot-bound Trees:

Both types of root systems are perfect for temporary placement in a community gravel bed. Bare-rooted trees are held until they can be planted; pot-bound trees until their root systems can be corrected.

right ways to install a gravel bed…and a few wrong ones as well.

Gravel beds may range from the elaborate, such as the 3-sided, sunken bed at Fargo, ND Park and Recreation (top photo), to as simple as a pile of gravel on an old parking lot (bottom photo). Photo credit: A. Dierich.

How does a CGB work? "Heeling-in" versus growing. Unless you are an avid gardener or a horticulturist, the term "heeling-in" may be a bit foreign because again, it doesn't inspire a logical image.

When bare-root plants are purchased, their roots can dry out quickly and if left to dry out too long, the plants die. If they can be planted immediately after they are purchased and delivered, that is the ideal situation. However, if they can't for whatever reason, those roots need to be kept moist and protected. One way to do that is to temporarily cover them with something that will help keep them moist and alive, aka "heeling-in."

Ideally, bare-root trees would be planted immediately after they were delivered or purchased. However, the weather might not permit it; there may not be enough available labor to plant the 500+ trees immediately; or summers in the area may be chronically hot, dry, and windy and the community may not have the capacity to water those trees two times a week. Photo credit: J. Hermann.

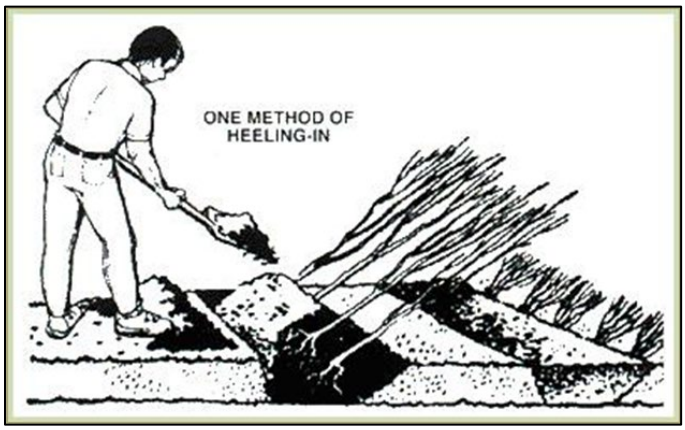


Image courtesy boydnursery.net

Heeling-in plant roots is a longer-term alternative to putting the roots in a bucket of water or covering them with a tarp.

For centuries, bare root plants were heeled-in shallow ditches in the ground, slanted so the growers could tell the difference between planted trees or shrubs, and those only temporarily held.

Today trees and shrubs are heeled in at an angle or upright. **Upright is most common in CGBs.**

Since the heeled-in plants are pulled ("lifted") within a few days or weeks, it was important to bury them with a material that would be loose, hold the moisture, and not pull and tear off roots when the plants were lifted. Coarse sand, sawdust, straw, and wood chips (photo to the right) were commonly used to bury the roots.

Gravel, rocks, coarse sand…why not organic mulches? Well over a century ago, growers started using more coarse sand and gravel to heel-in their bare root plants for a few good reasons:

1) Gravel and sand doesn't break down…they last forever. 2) It is difficult for disease pathogens to live in sand and rocks…there's little organic matter for those pathogens to make a home. 3) When plants are lifted from sand and gravel, relatively few roots are torn off…the sand and gravel just roll off them. 4) Coarse sand and gravel give the roots what they need: soil oxygen, moisture, and room for unrestricted growth.

A close up of pea stone (small diameter rock) on the left and an example of heeling-in coarse sand to the right.

What size of trees and shrubs can be installed in a CGB? Back to an earlier statement: this is not a guide for growing plants, rather, its intent is to successfully hold them for a while. Plants installed in a gravel bed do not put on any noticeable growth above ground for two reasons: 1) they are only in the bed for a short time – rarely longer than four or five months, and 2) rocks and sand have no nutritional value for plant growth.

If the goal is to plant 10 foot tall maples in the autumn or 3 foot tall forsythia, then 10 foot tall maples and 3 foot tall forsythia should be heeled-in the CGBs in the spring. Having said this,

most plants will grow expanded root systems while in the gravel; the longer they are in gravel, the greater the root system.

If rocks and sand have no nutrients, how does a gravel bed keep trees and shrubs alive for months? Roots need four things to grow and keep the plants alive: oxygen, moisture, energy, and growth regulators (hormones). Oxygen and moisture are necessary for the release of energy stored in the plants (carbohydrates), energy that allows the roots to grow. A gravel bed has lots of pore space that is shared by oxygen and moisture.

All bare-root trees start out as field-grown plants that are harvested in the autumn, stored in coolers over the winter, and shipped out in the early spring. When a community or group gets bare-root trees or shrubs, they have lots of stored energy courtesy of the previous growing season.

Hormones are necessary to kick-start the growth of roots, and those hormones are largely produced in the buds and growing tips above ground. Nursery-grown trees and shrubs are impressively complete and efficient systems.

What is meant by expanded root systems and is that an advantage? With few exceptions, most species will develop larger root systems during their extended tenure in gravel. If the bare-roots plants will only be in gravel for a month or less, there will not be a lot, if any, new root growth; the roots will be in a "holding pattern." However…

There are plants if left in gravel for as little as eight weeks that produce remarkably larger, fine-root systems. Examples of those plants include birches, elms, spirea, Eastern redbud, and Northern white cedar (arborvitae).

Root system of a Heritage oak after 12 weeks in a CGB.
Photo Credit: S. Papiz.

For most plants, the ideal amount of time for developing extensive root systems is 12-20 weeks, right in time for autumn planting. A "performance" protocol for the species evaluated by the University of Minnesota is included in **Part 6**, with a complete species evaluation in the **Appendix**.

Dysfunctional root systems are not death sentences. Finally, dysfunctional, pot-bound root systems can be completely corrected by "pruning" the root system and placing the plants in a CGB for a few weeks, usually 8-12 weeks.

In fifteen years at the University of Minnesota, hundreds of such dysfunctional root systems have been converted to normal and functional root systems via a CGB with no mortality. In as few as eight weeks, new root systems can be regenerated with plenty of time for late autumn planting. There are more details on this practice in **Part 4.9**.

The root system of a pot-bound birch, 8 weeks after root pruning and placed in a CGB. Note the partial remnants of the old, encircling root system and the new roots growing out into the gravel medium.

Is a CGB right for your community or project? Community gravel beds are not for every community, neighborhood, service or non-profit group planting project. However, if searching for a way to 1) reforest on a budget, 2) use a wide selection of plant materials, 3) use trees and shrubs light enough for volunteers to easily handle, and 4) plant trees and shrubs in the late summer or autumn when work pressure or heat and drought pressures are at their lowest, then a CGB should be considered.

Trees and shrubs are primarily harvested as one of three types: bare-root, containerized, balled-and-burlapped (B&B), or spade-dug; each type has its own advantages and disadvantages.

Bare-root plants have some distinct advantages. They are the lightest in weight (rarely more than 20 pounds), and cost the least (typically 20% or less of B&B trees, 30% or less of containerized trees of similar sizes). They are available in a wide variety of sizes (24-36 inches tall and larger), their species selection is often the most diverse, and their root systems are fully visible (they have no soil covering their roots).

However (there is always a “however”), large tree sizes (greater than 10’ tall or 1-3/4” caliper for shade trees, or 4’ tall for evergreens) are often limited or not available as bare-root plants, bare roots dry out easily, and nursery availability is limited to “leaf off” season (early spring, sometimes autumn).

Bare-root, 10 foot tall trees. There is no way a person could handle them as easily as this if those same trees were containerized or B&B. Each of these trees weighed less than 20 pounds. Photo credit: J. Hermann.

"Fall is for planting." Weather-wise, there is compelling evidence for planting in late summer through early autumn because weather extremes are less unpredictable and limiting. For instance, late summer and early autumn soil temperatures fall in the optimum range (70°-80°F) that is necessary for the stimulation of new root growth and recovery after transplanting. This allows newly planted trees the opportunity to take up moisture well into the traditional late autumn/early winter months (before the ground freezes).

Weather conditions, coupled with the normal reduction in demand for water by trees and shrubs in autumn months (especially compared to unpredictable summers), have been some of the main reasons that arboreta, garden centers, nurseries, and gardening magazines have promoted the "Fall is for Planting" campaign for decades. The bottom line: greater survival rates, less labor required for continual watering, and less water usage.

Freshly-lifted gravel bed trees on their way to an autumn planting in Hibbing, Minnesota. Photo credit: A. Dierich.

But wait, there's more! Springtime planting can be unpredictable weather-wise (cold, rainy, windy), and chaotic when there are other community chores that must be done. Also, getting springtime volunteers can be a real challenge given conflicts with school and other springtime commitments.

Waiting until later dates when the weather is better and time is not a pressure point are often the main reasons why communities turn to planting those bare root trees and shrubs, freshly lifted from their CGBs in the late summer or autumn weeks (late August through October in the upper Midwest).

Part 2: Locating a CGB, design options, and materials

2.1 Best bed locations. There are relatively few restrictions for finding the "perfect" spot for a CGB. Here are a few important tips:

2.1.2 If at all possible, do not locate it on productive soil…please. It's not necessary and can actually lead to some pollution of the gravel by the underlying soil, and it's a waste of good, growing soil. **Preferred sites include old parking lots, roads or alleys**; any site where the groundcover is mineral (e.g. gravel, asphalt, or concrete) is very suitable for a CGB. Likewise, avoid sites where spring floods or heavy rains would submerge the CGB.

This CGB was located on a concrete, seldom-used, municipal maintenance lot. It was constructed in a way that it could easily be dismantled if there was a need to repurpose the area. Photo credit: S. Papiz.

2.1.2 Shelter from prevailing winds and full sun light will greatly reduce the frequency and volume of irrigation water necessary to keep the gravel and plant roots moist.

2.1.3 A source of nearby water is absolutely necessary. This can be a pond, a spigot from a well, or other public water source, or a fire hydrant. With a community's permission, a fire hydrant can be fitted with a water meter and smaller hose adaptor.

2.1.4 If vandalism is anticipated, a CGB that is secured by a 6-8 foot chain link fence, or is at least out of sight would be a logical location.

2.1.5 If animal browsing is projected to be an issue, especially deer or rabbits, exclusionary fencing would be very desirable.

2.1.6 Access by trucks or tractors will greatly simplify the stocking and subsequent harvesting of the trees and shrubs.

This CGB and staging area in Racine, Wisconsin is fully accessible to larger equipment and is enclosed within a 6 foot high, woven wire fence.

2.2 Design and material options. Gravel beds for heeling-in trees and shrubs range in square footage, type of stone and stone mix, stone depth, and construction design, depending on the nursery stock size, and number of trees or shrubs that need to be installed. A rule-of-thumb to follow is "simpler is better."

2.2.1 Design option one: Uncontained. If the CGB is intended to be short-lived (a few months to a couple of years) for time-limited projects, an uncontained pile of stone will work well, preferably on little-used concrete, asphalt, or gravel surfaces. The only constraint on the size of the CGB is the square footage of the available ground cover. Yes, the gravel on the edges will spill out a bit since there won't be anything containing it, but it does not create an unmanageable situation. An occasional sweeping around the edges and scooping the gravel back on the pile is all that is necessary.

If that isn't appealing, place sand bags or something similar and temporary around the perimeter of the gravel pile. For heeling-in large trees and shrubs or large numbers of them, this is the least expensive CGB design.

2.2.2 Design option two: Contained. If the bed will be used for a longer period and a more contained system is warranted, three or four sides of the gravel pile can be contained with concrete blocks, concrete or polyethylene traffic barriers, pressure-treated construction lumber, or landscape timbers.

Three-sided or four-sided CGBs with the ability to remove one side are the preferred design options for these more permanent structures. If one side is absent or removed, the gravel and plant materials can be installed and harvested with mechanical equipment (e.g., tractor and front-end loader), eliminating most of the labor-intensive work associated with installing and harvesting by hand.

Fargo Parks and Recreation's 3-sided CGB. A permanent fixture of their planting program. Photo credit: A. Dierich.

One of our favorite CGBs (we like repurposing). To the left, the bins when they served as a community garden compost and debris facility. To the right, repurposed into their CGB. Woven wire fencing prevents deer and rabbit browsing, and the sand bags retain the gravel within the bins.

The **four-sided or completely contained CGB design** is generally recommended for smaller volumes, and smaller tree and shrub sizes. Again, a variety of materials can be used to contain the gravel at the desired depths. One option for a contained above-ground

CGB is a livestock watering tank or even a wading pool, ideal for smaller numbers (50 or less) of smaller-sized plant material (seedlings or 1-2’ liners).

If the community or group does not have access to mechanical equipment for stocking and harvesting the CGB, then a four-sided system is an appropriate option. As mentioned, the only drawback to a completely contained gravel bed is that all stocking and harvesting must be completed by hand (and shovels, and backs).

A classic example of a four-sided, above-ground CGB.

2.2.4 Containment options. **Concrete** traffic barriers are large, heavy (8’ long x 24” wide x 34” high = 3,325 pounds), and require mechanical equipment (forklift tractor) to move and place them. Smaller (8”x8”x16”) concrete blocks are much lighter (28 pounds) and can be placed and replaced by hand. A potential limitation is their height (8”) and therefore the depth of gravel they can contain at the edges.

As a concrete compromise, larger concrete building blocks (36” tall) are substantially larger and heavier (2439+ pounds), are very stable and long-lasting, and can be easily constructed if the right equipment is available.

This CGB was contained on three sides by concrete traffic barriers. Do not buy them if avoidable; use them only if the community has barriers from former projects. Photo credit: J. Busiahn.

Large, pre-cast concrete barriers make very strong gravel bed barriers, but they do require the right heavy equipment to handle them. This community (Bemidji, Minnesota) built their bed to serve them for many years. Photo credit: Bemidji Parks and Recreation.

The completed bed, fully stocked with bare-root trees. Photo credit: D. Ellis.

2.2.5 Temporary traffic barriers present another option. Their heights range from 24" to 42", lengths from 5' to 8', and when dry weigh between 35 and 85 pounds. Their stability is provided with water, weighing at least 400 pounds when reasonably full. During the winter, they can be drained, or simply add a gallon of antifreeze to prevent potential ice expansion and cracking of the barriers.

Plastic temporary traffic barriers used in a three-sided gravel bed.

The temporary barriers (less than 40 pounds dry) lock together and have capped fill-holes for adding water, water and antifreeze, or sand. They also have drain plugs on the bottom if they will be emptied and stored for the winter.

2.2.6 Pressure-treated wood is a construction option if no heavy equipment is available for handling concrete blocks or traffic barriers. Sides are generally constructed with 2”x10” pressure-treated dimensional lumber, at least two boards high. To maintain the stability of the side boards, 4”x4”x4’ pressure treated posts are installed to the outside of the walls. As an option to 4x4x4 posts, 5 foot steel U-fence posts can be substituted. There are more details on construction in **Part 3**.

If pressure-treated landscape timbers are used to contain the gravel, pre-drill holes for 3/8 inch rebar and install them every 24 inches.

Metal hardware. If pressure-treated landscape timbers are used, 24”x3/8” rebar (reinforcing steel bars with ridges) is driven into pre-drilled holes through the timbers. Rebars connect the timbers to each other better than nails or screws, and if long enough, are driven through the timbers and into the soil or whatever is below the timbers for stability.

All other metal hardware should be rust-resistant (stainless steel, aluminum, galvanized steel). Since the longevity of a gravel bed is never completely clear when they are built, it is recommended that all attachments are either screwed or bolted for easy disassembly, rather than nailed together.

2.2.7 Livestock water tanks, wading pools, and repurposed containers are available in a wide variety of sizes and volumes. They need to be constructed of galvanized steel, high or low density polyethylene, or rigid PVC (no inflatable wading pools). All tanks, wading pools, and repurposed containers must be able to provide a minimum depth of gravel, and must have a drain plug or drain well.

If a drain plug is not present, then a series of 3/8” diameter holes can be drilled near the bottom of the tank or pool. All CGBs must drain water well or the plant roots will die from lack of oxygen.

Quite possibly our favorite CGB (remember, we like repurposing). These discarded roll-off dumpsters became perfect CGBs. When it is time to plant out the trees, the dumpsters can be loaded up and transported to the planting sites. Ingenious!

2.2.8 Gravel. Because the term "gravel" has so many regional interpretations, it can range from rounded, washed river gravel to angular aggregate, sized from 0.1 to 3.0 inches in diameter. All can be used in a gravel bed to varying success. A commonly used stone for heeling-in bare-root trees and shrubs is termed "pea stone," theoretically because the size and shape is similar to a pea, rounded and about 0.1-0.35 inches in diameter.

The small size of pea stone and its poor interlocking behavior are likely the reason why it has been popular with nurseries and communities installing heeling-in beds with gravel as the medium. Small-sized, angular stone may be used for a CGB, but the results are not as good as using pea stone.

Since the pore spaces of pea stone are smaller than they would be with larger stone, the gravel tends to retain a higher humidity level, which is preferable for root growth. At the same time, there is sufficient pore space available for oxygen, which is critical for living root respiration and growth.

In some CGBs, smaller sized materials such as calcined clay or coarse sand may be mixed in with the gravel in order to hold more moisture for a longer period of time, reducing the frequency of irrigation and net water loss due to evaporation or percolation. When calcined clay or coarse sand is added to pea stone, a common ratio is 1-3 parts clay or sand to 7-9 parts gravel, by volume. To be most effective, the amendments should be thoroughly mixed in with the pea stone.

2.2.9 Weed barrier or landscape fabric. These woven fabrics were saved until last, primarily because they are normally not necessary. Woven fabrics made of polypropylene, which theoretically should last a long time, can be purchased in "bolts," ranging from 32" to 72" wide, and 33' to 300' long. When used, it is to keep the stone from "disappearing" into the soil, **not for preventing weeds**.

Part 3: Building a CGB

3.1 Start with the depth. A common stone depth for gravel beds is 15 to 18 inches, which is generally adequate to install most bare-root plants and bury the first main order root to a depth of at least 4 inches.

Pea stone tends to dry out easily in the top inch, even with irrigation; therefore, burying roots with at least 4 inches of gravel creates a more humidity-stable environment for the root systems. Some gravel beds may have depths of 24-30 inches, but that is rarely necessary.

A 100 square foot community gravel bed in Marine on St. Croix, MN, with 18 inches of pea stone as the medium. Note that these supporting posts are located to the inside of the bed, and that all hardware attachments are galvanized lag screws. Photo credit: J. Goodfellow.

3.2 The size of the CGB is dependent on the size and number of plants to be installed. For instance, if 1.5" caliper shade trees will be the main clients, the diameter of their bare root systems will be approximately 24 inches (2'). That means each tree's root system requires 4 square feet of gravel area (2'x2'=4 ft²).

If the planting project specifies an inventory of 50, 1.5" caliper trees, the CGB will need to contain a minimum of 200 (4x50) square feet of gravel area to hold those trees if installed root tip to root tip.

Conversely, if the planting project specifies an inventory of 50, 2 year old evergreen transplants, their root system width is less than 12 inches, so each tree requires 1 square foot. A CGB with 50 square feet will easily accommodate those trees.

A county forestry department in Minnesota that is serious about using gravel bed trees to reforest. The gravel is 18 inches deep, the beds are three-sided using concrete traffic barriers, and at any one time, more than 1000 trees and shrubs can be heeled-in for the summer.

Finally, if the gravel bed will be used to recover containerized, pot-bound root systems, and if the trees were in #15 containers, the spread of the branches would probably be the defining measurement for calculating required square footage. A flowering crabapple in a #15 container would have a branch spread of approximately 40 inches, so the required square footage would be (about) 11-12 square feet (40"x40" ÷ 144 sq. inches = 12 square feet), and a CGB that would hold 50 of those trees would need to be at least 600 square feet.

The opposite tactic can be taken when calculating how many plants will fit into a given size. For instance, a circular livestock watering tank that measures 8 feet in diameter and 24 inches deep has 50 square feet of gravel area. That would accommodate those 50 evergreen transplants, or 12 of the 1.5" caliper trees, or 4 of the flowering crabapples.

Galvanized steel or polyethylene livestock water tanks are excellent, short-term CGBs and they are available in a wide selection of diameters and depths. As with any type of container, **they must have a drain plug that is left open. Standing water kills roots.** This tank could hold a dozen 1.5" caliper trees.

For guidelines on estimating the root system sizes of various nursery-grown plants, consult **ANSI Z60.1, the standards for nursery grown trees**. Sometimes, though, it will be necessary to physically visit and measure the spread of branches.

3.3 The shape of the CGB is irrelevant, unless it is restricted by the shape of the available installation area (e.g., the parking area is a rectangle, 12 feet wide by 60 feet long), or the container (e.g., the wading pool is 5 feet in diameter). In most cases, CGBs installed on driveways or other hard surfaces will not need to be leveled.

This CGB is a free-form bed and is a permanent feature. The pea stone is 18 inches deep, and the sides are concrete building blocks commonly used for retaining walls in landscapes. At its extreme length, it measures approximately 40 feet, and it has the potential to hold 100, 1.5" caliper trees each season.

3.4 Leveling. If installed on sloped land, leveling the CGB has nothing to do with the performance of the bed (unless it's that wading pool or livestock tank), and more to do with the aesthetics of the system. Usually, if the bottom course of a wood, timber, or block-framed CGB is leveled, it won't be necessary to level up subsequent courses (layers); consider it good enough.

If the CGB is built on soil, it pays to partially bury that first course of wood, timbers or blocks by a couple of inches. This will lessen the chance that it will be "kicked out" from the force of the gravel.

3.5 "Squaring up" the bed. The same can be said about squaring up a constructed bed. A parallelogram, trapezoid, or rectangle may all have the required square footage, but professionally, a square or rectangle will look better...or at least more purposeful!

To "square up" a square or rectangular bed, use the formula where "the hypotenuse is the square root of the sum of the squares." In the case of a rectangular bed with the short side 6 feet (36 feet if squared) and the long side 18 feet (324 feet if squared), the hypotenuse would be the square root of 360 [$\sqrt{(36+324)}$] = 19 feet.

Now use that hypotenuse to square up the opposing corners. Only one corner/two sides need to be squared up since the other side measurements will automatically be square.

Squaring up a long, rectangular bed. The bed measurements to the left (a, the long side) and foreground (b, the short side) are known. The person second from right is holding the calculated hypotenuse, stretched from the upper left corner to the lower right (yellow dashed line). The person to the far right is moving the tape measure at the correct distance (a) until it lines up perfectly with the calculated hypotenuse, aka Pythagorean Theorem. This process works much better and faster with three tape measures and at least three people helping out. Once that corner on the lower left is squared up via this process, simply measure the other two sides off the existing sides and you have a squared up bed.

3.6 Providing side support. If the CGB is constructed from dimensional lumber or landscape timbers, support on the outside of the bed will be necessary to prevent the sides from bowing or pushing out, regardless if it is a three or four-sided bed.

If the bed is constructed 18 inches high (two, 2”x10” pressure treated boards high), then outside support posts of wood or metal will ideally be installed every 2 feet. If the CGB is constructed on a solid surface such as a concrete or asphalt pad, metal posts (round or t-fence posts) work well for outside support.

Ideally, the outside support posts, in this case pressure-treated 4”x4” posts, are buried to a depth of 2-3 times the distance they are above ground - if the CGB is installed over landscape soil. For instance, if the above ground bed is 18” high, the posts should be 18” above ground and at least 36” inches below ground. This rule of thumb also applies if the outside support is via steel fence t-posts.
Note in this photo that the side boards are attached with galvanized steel lag screws.

This CGB was installed on an existing concrete pad and used round metal posts for the outside support. Note that the posts sit in holes in the concrete base. Also note the novel use of metal handles on the side boards. The side board can be lifted up, posts and all, for easy stocking and harvesting of the trees, or seasonal disassembling of the CGB. Again, all attachment or support materials are either galvanized steel or aluminum. Photo credit: S. Papiz.

3.7 Weed barrier fabric is occasionally used as a ground cover under the gravel, but only when the CGB is installed over soil. If the fabric barrier is not installed, the gravel will sink into the soil, which only becomes a problem if the trees are installed and harvested with a front end loader. Soil becomes mixed in with the gravel and after a few installations and harvests, the gravel is fairly clogged with soil and loses its original ability to allow the plants to be pulled from the gravel with a minimum of root loss. This is one more reason to not construct a CGB on soil. The fabric should be dimensionally large enough to pull up and attach to the sides of the CGB.

A CGB installed over bare soil. Note the black weed barrier fabric that lines the bed and is attached to the side boards near the top of the bed. This woven fabric allows oxygen and water to pass through but contains the pea stone from mixing in with the subsoil. Also note the deer barrier fencing around the bed. Without it, the deer pressure in this area would have converted the CGB into an "all they can eat" buffet.

If plastic is used as a liner, poke holes through the bottom to allow adequate drainage.

3.8 What not to do. There is a temptation to provide some winter stability or protection for the tree and shrub roots heeled in a CGB, but it is a 1) waste of time, and 2) mistake. First, a CGB is

not intended to be a winter bed; all plants should be planted out in the landscape by the end of the growing season.

On rare occasions, the end of the season may come earlier than expected (surprise!) and the plants must overwinter in the beds. No worries. Even in the upper Midwest, those plants rarely suffer cold temperature damage during the winter and can be planted out the next spring.

Second, all of the efforts to create a more winter stable environment for the roots were a waste of time. A pile of gravel works just as well. Placing insulation, straw or tarps over the gravel to prevent freezing is usually unnecessary, even with beds in northern Minnesota.

Constructing the bed below grade is a huge mistake for a number of reasons. It's very hard to install and harvest the trees, and unless the subsoil is beach sand that percolates at a rate of one inch a minute, those below ground beds end up as swimming pools. When that happens, a sump pump must be installed in each bed to remove the excess water.

Huge mistake and full disclosure: our first research gravel beds were built below grade and lined with water resistant barriers (aka, house wrap). A lot of wasted work and time and materials. Every time it rained, the water in each bed had to be pumped out.

Those sunken beds after a rainstorm. Each section of the gravel bed had to be drained with a sump pump after every significant rain event. We offered up the beds as 50 meter lap pools for the 2008 Olympics, but were declined. Their loss.

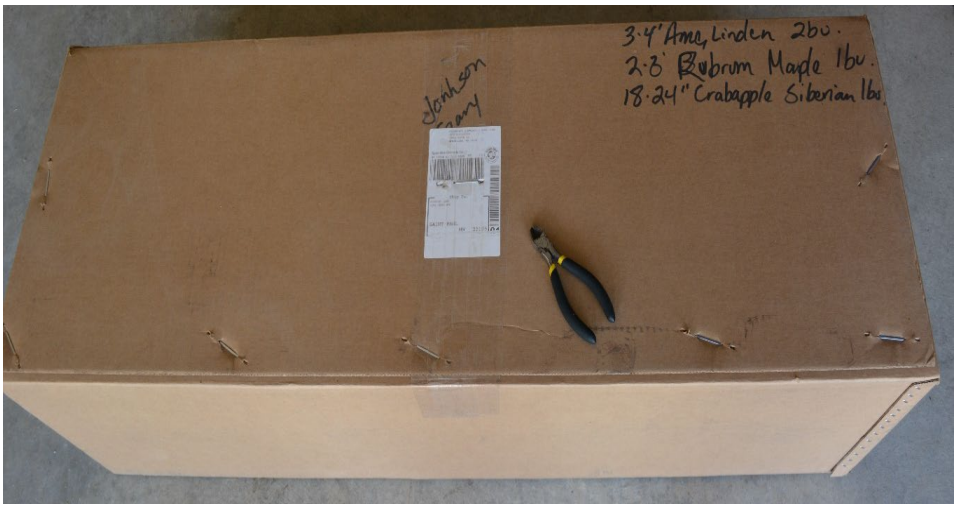
Part 4: Stocking a CGB: when to order trees, heel them in, and "sweat" it

Stocking: The process of heeling in trees and shrubs in a CGB. Stocking involves root types (bare-root vs. containerized), number of plants, and time of season.

4.1 Bare-root plant sizes. Most CGBs stock bare-root trees and shrubs ranging in size from 1-3' tall (shrubs and evergreens), 3-7' (flowering trees), to 0.75-2.0" caliper trees. In general, smaller plants fare better than larger trees, but that is largely species dependent. For instance, bur oaks (*Quercus macrocarpa*) rarely do well in a CGB when taller than 3-5', whereas 1.5" caliper honeylocusts (*Gleditsia*) and river birch (*Betula nigra*) are well-suited to gravel, and 2.0" caliper 'Purple Robe' black locust (*Pseudoacacia)* does entirely too well. I've witnessed Chris Starbuck from the University of Missouri successfully stocking their beds with trees 3 inches in caliper and larger!

4.2 Sourcing plant materials. For most communities, the size of bare-root plants selected are functions of 1) budgets, 2) who will be planting the trees, and 3) availability. Most communities can set up accounts with wholesale (versus retail) nurseries that grow and sell bare-root trees and shrubs. It is strongly advised to develop a working relationship with a wholesale or retail nursery that is close to the community or at least within the community's state. For those instances where a community or group cannot set up wholesale accounts, plants can be purchased through a local retail nursery that has the ability to order from wholesale nurseries. Purchasing these plants from a retail nursery will be more expensive, but those costs are still significantly lower than their containerized or balled-and-burlapped counterparts.

Another option for sourcing bare-root plants is from mail-order nurseries. As with finding wholesale tree nurseries, let your fingers do the walking and your internet browser the finding. Type in "bare-root red maple trees" for instance, and then survey the nurseries that come up. Some will be wholesale-only nurseries, some will be retail, mail-order nurseries. There are many good retail mail-order tree and shrub nurseries in the country. Your challenge will be finding the one that is located closest to your community and has a good reputation.



Typical shipping packaging from a bare-root mail-order nursery. Note the interior of the box containing the trees is waxed, and the trees are further wrapped in plastic to retain moisture.

4.3 Minimum orders are very common criteria for wholesale nurseries. Trees may only be available in bundles of 10 or 25 (see following screen shots). If one community does not need those numbers, an option would be to contact other communities close by and find out if they would be willing to share a tree order. One community may need 10 of the 25 trees, and perhaps another community needs the other 15.

A more altruistic move would be to donate the extra trees to a local school or service group for an Arbor Day or Earth Day planting. We don't advocate "stealth planting" the rest of the trees on public lands that could really use some canopy without creating maintenance problems, but ...

BIRCH, RIVER
(BETULA NIGRA)

Size	Light	Hardiness
40' to 70'	Sun to partial shade	Zones: 4-9

# Per Bundle	Bundle Type	Size
25	Seedling (S)	12''-18''
25	Seedling (S)	18''-24''
25	Seedling (S)	2'-3'
25	Seedling (S)	3'-4'

Multistemmed is desired; native; graceful branching; easy to transplant; best not to prune in spring – sap "bleeds"; heat tolerant; cinnamon brown exfoliating bark; may drop some leaves during dry weather; seeds attract birds. Has

COTTONWOOD, MALE
(POPULUS DELTOIDES)

Size	Light	Hardiness
75' to 100'	Sun	All Zones

# Per Bundle	Bundle Type	Size
25	Root Cutting (RC)	18''-24''
25	Root Cutting (RC)	2'-3'
25	Root Cutting (RC)	3'-4'
25	Root Cutting (RC)	4'-5'
25	Root Cutting (RC)	5'-6'

Cottonwood is a rapid growing tree and becomes very

4.4 Learn to speak "grower language"

Liners: immature "not ready for prime time" trees or shrubs. Usually purchased and planted in the field or in containers (aka, lined-out) until they reach a more saleable size.

Seedling (S) or Rooted Cutting (RC) Liners: Plants grown from either seed or rooted cuttings. A 2-0 liner is two years old, having spent its entire life in a liner bed (aka, grown in soil, tightly-spaced rows). A 3-0 liner is 3 years old. Seedling liners can be variable in size and color. Liners from cuttings are clonal and exact replicates of the parent plant.

Transplant (TR): Plants that have been grown in liner beds, transplanted to another bed after a period of time, and then grown for additional years. A TR 2-2 would be four years old, having spent the final two years growing in the nursery after being transplanted once. A TR 3-2 would be five years old. **Transplanted liners are always better in terms of root development than seedling or cutting liners; therefore a TR 2-2 is a much better liner than a 4-0 in terms of root development and transplant success.**

Whip (Wh or W): Trees with one year old tops. The root systems can be two or more years old. They may have been grown as a seedling liner for a year or two, cut back to the ground, and a new shoot was selected and trained as the leader, or they may have been grafted onto a 2-4 year old root stock. Whips are usually straight as an arrow, with no noticeable branching.

Lightly Branched (LB or LBr): The next stage beyond whips. Straight leader and relatively few, short branches along the leader.

Branched (Br): More and better developed branches compared to a lightly branched tree.

Heavily Branched (HB, HBr): Several stout, well-developed branches and larger caliper trunk.

Caliper: For bare-root shade trees (e.g., maples, oaks, birches), the thickness (diameter) of the tree's trunk, measured 6 inches above the first main-order root.

Diameter at Breast Height (DBH): Trunk diameter 4.5' above ground; a term used by foresters, not tree nurseries.

Flowering Trees (e.g., crabapples, hawthorns, redbud): Generally sold by height.

Evergreen Trees (e.g., pines, firs, spruces): Generally sold by height.

Shrubs (e.g., potentilla, ninebark, mugo pine). May be sold by height, height and width, or width (if they are spreading shrubs, e.g., rock cotoneaster, Blue Rug juniper).

Containerized (C) or Container-grown (CG): Trees or shrubs that have been potted up as field grown liners and finished up in a container or have spent their entire lives growing in a container. Not your usual plant for a CGB.

Field-grown (FG): As the name implies, these plants were grown in the field and then harvested as either bare-rooted or balled-and-burlapped (B&B) plants.

Balled-and-Burlapped (B&B): Plants harvested from the field with soil enclosing the root systems; not your usual choice for a CGB.

4.5 When should the bare-root plants be ordered from the nursery? Like most things, the sooner the better. Ideally, orders should be placed before the end of December for a spring delivery. The later the order goes in, the less likely all plant varieties and numbers will be available.

4.6 When do they go in the CGBs? This is largely a function of when the wholesale nurseries start shipping their bare-rooted plants in the spring. The plants will be "dormant," actually a state of physiological rest after being harvested from the fields in the autumn, and stored in controlled atmosphere facilities (less than 40 degrees F and humid) for at least three months. Communities in the southern states can begin stocking their CGBs as early as February. For the more northern states, April and May are the most common months for receiving and stocking the CGBs. Make sure the CGB is ready for stocking by the time the trees arrive.

Air temperatures are not a big concern. These trees and shrubs are fully acclimated to the normal temperatures in their cold hardiness zones because they have been held in cold storage for months. Once they are heeled-in a CGB, air temperatures above freezing will trigger these plants to slowly begin active growth. Soil or gravel temperatures are a bigger concern. If the soil or gravel is still frozen, it will be very difficult to plant them or heel them in gravel. Way too much like work.

What needs to be ready before the trees and shrubs arrive? Everything, including all of the labor force, tools, and equipment for installing the plants in the CGB, the space and materials for those plants that need to be sweated, and most important…water. Bare-rooted plants dry out quickly and it's easy to lose an entire shipment if they are not heeled-in upon delivery.

4.7 Hand work needed for installing plants in a four-sided CGB. This is a lot of work. Start by digging a single trench across the width of the bed, as deep as possible. Digging a trench in pea stone can be a bit frustrating because the stone tends to slump back into the trench (remember Sisyphus?), so it works best if two or three people are digging it and pulling the stone back. Place the trees or shrubs in the trench, and backfill with the excavated pea stone with one person holding the trees or shrubs upright. Repeat this step until the bed is fully stocked.

It is critical that there is at least 4-6 inches of stone over the root systems for two reasons: 1) stability, especially if it's a windy area, and 2) the stone directly around the roots will stay uniformly moist. The top inch or two can dry out quickly if the bed is in a sunny and windy area, but not the top 4-6 inches. Forget everything you ever learned about planting too deep. These plants are being temporarily heeled-in, not planted. Plus, the gravel is a wonderful media for oxygen and water diffusion, as opposed to a heavy clay soil.

Plants can be installed with all of their roots buried deeply in the gravel, or as with this bed, they can be partially buried in the dug trench and then pea stone can be mounded up to a depth of 4-6 inches over the roots, having the appearance of little volcanoes. Both tactics work just as well.

4.8 Sometimes "sweating" is a necessary step. Not what you may be thinking. "Sweating" is a process that **some** woody plants need to go through before they will begin active growth.

"Sweating" those trees, shrubs and vines that are in deep states of rest is a generations-old, reliable tree nursery practice that has very little (if any) research evidence to explain the process and why it works; but it works. It is a recipe that uses three ingredients to awaken those sleeping beauties: 1) Warmth, 2) Humidity, and 3) Time.

The Sweating Recipe

Step One. Separate the species to be sweated and bundle them up in bunches of 5-10, depending on their size. Do not mix species in a sweat bundle because different species usually require different amounts of time.

Bundle the trees or shrubs together by species. For ease of handling, bind the stems/branches together with twine. Wrap the roots in wet burlap or pack with wet straw, wood chips, or excelsior (curled wood shavings).

Step Two. Capture some warmth. Place the bare-root plants on the bare ground or the floor of a hoop house, barn or garage. If possible, temperatures should be supplemented if they are not in the 45-70°F range in the built structures. Warmth radiating from the earth is generally enough. Warmth from direct sunlight is too much and will likely parboil and damage the plants, so keep the bundles of joy shaded.

Step Three. Bring on the moisture, but only on the roots. Syringe the roots thoroughly (spray with a hose or dip into tank) and then **cover them with materials that will hold moisture, such as wet straw, wet burlap, wet excelsior** (aka, curled wood shavings). **Do NOT cover the stems and branches with these materials.** If for no other reason, buds need to be checked almost daily, so they need to be accessible and visible.

Step Four. Complete the greenhouse. Cover it all – roots, stems and branches – with clear or opaque plastic or light-colored tarps and if necessary, anchor down the edges to keep the interior warm and humid…just like a greenhouse…or a burrito.

A tree burrito. Use clear plastic or light-colored tarps to cover all roots and branches. Bricks or anything heavy can be used to weigh down the edges if necessary. Always keep the sweating process in an area away from direct sunlight, otherwise, the trees will be parboiled by the excessive heat and humidity.

Step Five. Start inspecting buds after 2-3 days. As soon as bud swell begins –usually recognized by enlarged buds and separating bud scales – it's time to pull those species out and get them in the ground or gravel bed. They are now ready to meet the tulips as long as outdoor temperatures are reliably near or above freezing.

Note the expanding bud, which indicates that active growth has started. Pull the trees from the sweating structure at this point and either plant them in the landscape or install them in the CGB.

How Long Does This Take?

It depends…on the species, the size of the nursery stock (bigger takes longer), and the length of time they have been in cold storage. Some plants may require only 3-4 days while others two weeks or longer.

Don't try to predict. Start the sweating with all of the "needy" species at the same time, and pull them or uncover the tops as the buds begin to break.

Which Species are the Needy Ones?

There's some controversy here. Depending on the resource there may be 16 to almost 40 different trees, shrubs or vines that either require or respond well to a good sweat. The Complete List of Sweat Lovers (see next page) was compiled from references and recommendations from over 14 national, wholesale nurseries.

The Complete List of Sweat Lovers

Trees:
Maples (*Acer)*
Serviceberry (*Amelanchier)*
Birches (esp. *Betula nigra*)
Musclewood (*Carpinus)*
Hickory (*Carya)*
Hackberry (*Celtis*)
Eastern Redbud (*Cercis)*
Pagoda Dogwood (*Cornus)*
Hawthorn (*Crataegus)*
Beech (*Fagus)*
Ash (*Fraxinus)*
Honeylocust (*Gleditsia)*
Crab/Apple (*Malus)*
Mulberry (*Morus)*
Black Gum (*Nyssa)*
Ironwood (*Ostrya)*
Amur Corktree (*Phellodendron)**
Plums (*Prunus)*
Ussurian Pear (*Prunus)**
Chokecherry (*Prunus)*
White Oak group (*Quercus)*
Skunkbush Sumac (*Rhus)*
Black Locust (*Robinia)**
Weeping Willow (*Salix)*
European Mt-Ash (*Sorbus)*
Lilac (*Syringa)*
Bald Cypress (*Taxodium)*
Lindens (*Tilia)*
Elms (*Ulmus)*

Shrubs and Vines:
Barberry (*Berberis*)*
Trumpet Vine (*Campsis)*
Variegated Dogwoods (*Cornus)*
Cotoneaster (*Cotoneaster)*
Potentilla (*Potentilla*)
Roses (*Rosa)*

*BE CAREFUL WITH THESE SPECIES: Check with your state regulatory agency to determine whether they are listed as invasive or aggressive in your state.

What if sweating is skipped?

1. They may experience a shorter growing season that first year.
2. Trees and shrubs may enter the winter with lower energy reserves due to the abbreviated growing season, and may be more likely to suffer winter season damage to roots, cambium and buds.
3. There may be less root growth that first season. Roots need photosynthates (sugars and starches) to grow.
4. People give up, think they are dead, stop watering and/or remove the sleepy ones.
5. Nothing…if the trees and shrubs have been sweated before they were shipped to you. Inquire whether this has happened from the nursery supplier.

4.9 An alternative CGB use: stocking pot-bound, containerized plants. This is a bit of an unusual use of a CGB, but a very effective way of taking pot-bound trees and shrubs that are otherwise good, healthy plants, and cultivating a new, normal, and functional root system. This process can be done at any time, and involves minimal labor and time.

Quite often, pot-bound plants never recover and develop a normal, functional root system, and die prematurely in the landscape. This birch lived for almost five years before it died. Its root system never developed well enough to stabilize the tree and "mine" the landscape soil for water and nutrients.

Step One: Prune the encircling roots. The method for pruning pot-bound root systems that was developed and field tested on hundreds of trees at the University of Minnesota in the early 2000's was termed "boxing." "Boxing" involves removing approximately one inch of soil and roots on four sides of the dysfunctional root system.

Pot-bound root system of *Acer* before "boxing."

"Boxing" with a saw (left) and the completed process (right). Think of that pot-bound root system as a (gritty) gyro, and you are slicing off four slabs. No need to slice any soil and roots from the bottom. Photo credit: D. Hanson.

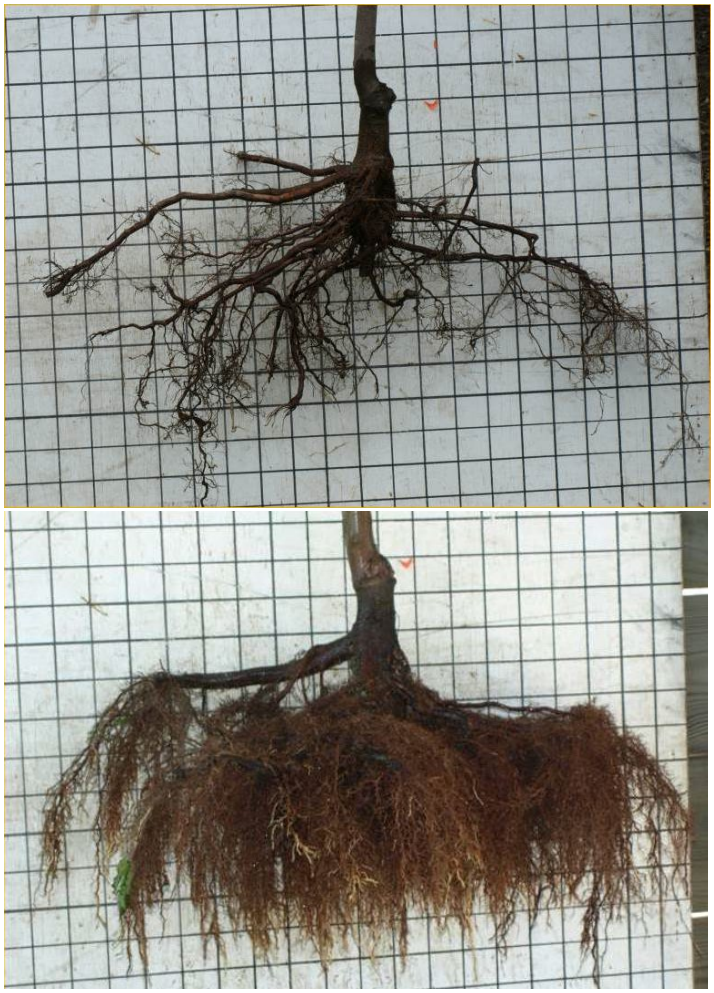
Step Two: Heel-in the boxed root system in the CGB. That's the whole process**.** Depending on the tree or shrub species and the time of the year, the root system recovery process takes between

1-4 months. During that time, new roots are formed that grow straight out from the root/soil ball, never again in an encircling pattern.

Two extremes of “boxing” and heeling-in a CGB. The top photo is a *Betula nigra,* 5 weeks after “boxing” and heeling-in. Bottom photo is an *Acer rubrum,* 18 weeks after the process. Note the dashed lines showing the original, “boxed” root system.

Part 5: Harvesting (aka "lifting") CGB trees and shrubs

5.1 Timing. There are several "depends" when it comes to deciding when to lift plants from the CGB. If the purpose of the CGB is to hold spring purchased plants until they can be planted out, then all of the plants will likely be lifted and planted within two to four weeks. If the purpose is to hold the plants until the dryness and heat of summer is over, then lifting will begin in late summer (late August in the upper Midwest). If the purpose is to recover pot-bound root systems, or develop a denser fine root system on bare root plants, then the timing is more species dependent.



An *Acer x freemanii* purchased as a bare-root tree in the spring (top) and after 12 weeks in a CGB (bottom).

Certain species develop fine and woody root systems in gravel in a short amount of time (5-8 weeks) such as *Betula, Viburnum, Malus, Cercis, Metasequoia, Ulmus,* and *Salix,* while others either take much longer (3-5 months) such as *Quercus macrocarpa, Aesculus glabra, and*

Amelanchier species, or never develop a very expanded root system. If the CGB is set up as three-sided or no sides, it is wise to stock the slow-rooting trees to the back, thus the last to be lifted. Fast-rooting trees and shrubs are best placed in the order where they will be lifted first.

This placement order doesn't necessarily relate to transplant success, but more to ease of harvesting. Any community that has installed fast rooting trees in gravel and didn't begin the harvesting process for three months or more learned how much work it is to lift a willow or an elm or even worse, a 'Purple Robe' black locust. This is doubly-reinforced if the CGB is four-sided and every plant is harvested by hand.

Some species do not develop many roots in a CGB such as *Aesculus glabra,* yet their transplant survival rate is reliably high (85% or greater). For those species, the CGB is a holding area, not much of a root development area. Other species such as *Rhus typhina* or *R. glabra* do well in gravel but are very sensitive to the time of the year they are lifted. Lift sumac in the summer, and it is likely they will all die. Move them in the autumn, and they have more reliable survival rates.

Suggested harvesting times are noted in the species performance table in the **Appendix**. If a community finds that certain species do not perform well in gravel, especially after they are transplanted, they shouldn't install them in a CGB again. Those species should be planted directly in the landscape in the spring. Species performance in CGBs is constantly an experiment. Even species that do not normally do well in gravel such as bur and white oaks, do well if they are installed as smaller trees, no taller than 4-5 feet.

5.2 Lifting. If the CGB is four-sided, all lifting must be done by hand, hopefully with a "crew" of enough people that two people can be pulling the trees up while one or two more are under-cutting the roots with shovels. There is no way around this; it is a lot of work for those trees and shrubs that love gravel and develop prolific root systems.

Do not worry about getting all of the roots when lifting. It is not necessary because there will be plenty of new roots to support the transplanted tree or shrub. Do not try pulling the trees out physically without cutting some of the roots and having other people to help. That is a good way to spend the rest of your life with a back injury, and it's not worth it.

If the CGB is open or three-sided, the lifting is much easier and better for the tree by using a front-end loader. If so, the lifting is a two person act. It is a simple process of using the loader to scoop up the gravel with one or two trees, followed by one person pulling the trees out of the bucket and shaking off the gravel, and finally the tractor operator moving on to the next trees in line. This process goes pretty quickly and without a lot of physical exertion.

One of our favorite pieces of equipment for lifting trees from a CGB. This front-end loader has been equipped with a “rock picker” bucket. As it lifts the trees, the gravel naturally falls off the roots, through the bucket, and back into the bed. If a rock picker bucket isn’t available, any front end loader bucket works well, just not as well as this one. Photo credit: J. Busiahn.

5.3 Keeping the roots hydrated during the delivery process. All of the time invested, all of the money invested is wasted if the roots of the lifted trees are not kept moist. An easy method is to immediately “bag” the tree/shrub roots in a plastic bag upon lifting them from the CGB. Immediately place the bags in a shady area if there are other trees to harvest.

Plastic bags work well if there are only a few trees and shrubs harvested at any one time, and the bags can be reused for the next batch of trees or shrubs. Fifty gallon, contractor strength bags are recommended for this technique.

Bagging up lifted tree roots before they dry out. Bags can be reused and if there are only a few trees being harvested at any one time (less than 20-ish), then this method works well.

Some CGB managers immediately dip the roots of lifted plants in a **hydrogel solution**. Hydrogel is a synthetic polymer (photo below) that comes in a dry form and is mixed with water to create a gelatin-like product (no taste to it and there's never room for it in any diet). It has no nutritional value, but it does coat plant roots and keeps the roots from drying out so rapidly. There are several trade sources for hydrogels and relatively speaking, they are not expensive.

Dry hydrogel crystals. When added to water, it results in a thin gelatin-like material that tree and shrub roots can be dipped in after harvesting to reduce moisture loss and root death. Photo credit: growtent.eu

If many plants are lifted at the same time from a CGB, the plants can be either dipped in hydrogel solution, or quickly watered down and then loaded into a van, truck or trailer. At that point, the plants are all covered with a tarp to reduce moisture loss and ideally planted soon.

As these CGB trees are lifted, their roots are dipped in the livestock water tank containing hydrogel. Photo credit: J. Busiahn.

Ideally, this is how CGB harvested trees and shrubs would be transported to the planting sites. The roots can be kept moist for days since they are not exposed to drying sunlight or winds. Photo credit: J. Busiahn.

Harvested trees can also be transported in trailers or trucks as long as the roots are kept moist and protected from sun and wind. Photo credit: S. Papiz.

If planting time is lengthy, rather than keeping the plants waiting on the trucks or trailers, they can be temporarily stored on the planting site in large waste containers, livestock watering tanks, or inexpensive wading pools.

One community's creative technique was to place each harvested tree (after dipping the roots in hydrogel) in a #40 growing container. The container is immediately filled with moist wood chip mulch, transported to the planting site, and staged at the locations where they will be planted.

When the volunteers dig a hole large enough to accommodate the root system, the trees are pulled from the containers, planted, and the mulch that kept their roots moist in the containers is used to mulch the newly planted tree. Very clever and a perfect method for projects that utilize large numbers of volunteers.

Trees from this CGB, all of which are planted out by volunteers, are immediately dipped in hydrogel after they are lifted from the gravel, placed in #40 growing containers that are then filled with wood chips to keep the roots moist. Photo credit: D. Ellis.

These trees will be transported to the new landscape and placed where they are to be planted. After planting, the amount of wood chips in each container is just right to mulch the newly planted tree. Photo credit: D. Ellis.

Part 6: Species and size performances in a CGB

6.1 Assessing gravel bed suitability. Since the Urban Forestry Outreach and Research (UFOR) lab at the University of Minnesota began conducting research on community gravel beds and tree species performance in 2006, several protocols have been designed to measure root mass development.

Arguably the most accurate is the water displacement method (Archimedes' principle) which measures the volume of roots prior to gravel bed installation and subsequently after the trees have been harvested by submerging the root system in a container of water. The measured outflow of water (ml) is equal to the volume (cubic centimeters) of the root system. This provides an accurate measurement of the volume of new roots produced. However, this is a very tedious and time-consuming tactic, bordering on academic, and not practical for the typical gravel bed manager or anyone who has any desire for a social life.

The root assessment method ultimately recommended is one that has been used for over eight years in the UFOR gravel bed studies and is designed to be intuitive and reliable with minimal training of those who are harvesting and assessing root system development. With this method, harvested roots are held against a gridded white board with a minimum of two people evaluating how much of the white board background is visible through the root system, using a progressive grading system from 1-5. A grade of 1 indicates most of the white background is visible and a grade of 5 indicates that little or no white background is visible.

Reviewing the four examples, it is easy to identify a root system graded as #1 or #5. Grades in between are a little more subjective and take practice to differentiate among #2, #3, and #4. Also, the example immediately below the #5 bur oak is a #5 freeman maple, which has a much broader root mass, but the density is the same as a #5 bur oak.

How would you assess this root system on a 1-5 scale, regardless of species?

6.2 CGB suitability rating. The gravel bed suitability rating is a combination of root system development and survival rates of the trees and shrubs held in gravel. This does not mean the plants will survive any better than any other type of nursery stock (i.e., containerized, B&B), once planted out in the landscape.

To that end, an additional **transplant rating** was developed to document how well trees and shrubs survived after transplanting from the CGB to the landscapes. **Transplant ratings** are determined by inspecting the plants at the end of the growing season one year after planting. The rating reflects both the survival rate as well as any amount of dieback the plant may have suffered.

Ideally, this is what trees planted out from a CGB would look like, one to two years later. This specimen is a coffeetree (*Gymnocladus).*

Generally speaking, more developed root systems have resulted in more successful transplant ratings, but not always. Some plants produce few if any new roots while in gravel, spending their time in an altered state of consciousness, yet still survive transplanting very well. Ohio buckeye is a good example of that. However, other species that do not produce many new roots often experience lower transplant ratings, such as many of the oaks and silver linden.

In limited studies, bare-root trees planted directly in the landscape in spring and those that spent the growing season in gravel and were subsequently planted out in the autumn showed no measurable differences in root system development. This is consistent with the results that one wholesale nursery reported (Bachman's Wholesale Nursery, personal communication) when they planted out gravel bed trees side-by-side with other root stock types (bare-root, containerized, balled and burlapped).

However, at the community level, late summer/autumn planted gravel bed, bare-root trees consistently had higher survival rates than those planted bare-root in the spring. This was largely attributed to the water demand of the trees and the inability of the communities to supply water to those spring planted trees throughout the typically unpredictable summers.

Tree size matters. In general, trees that were smaller in size (5-7' tall and less) were better suited to CGBs and had higher transplant ratings than their larger counterparts. Oaks have been notoriously poor performers in gravel as larger, calipered trees, but did reliably well as smaller (5' tall or less, and smaller caliper). If a community intends on planting 1.5" caliper oaks, it is recommended that they be planted as containerized or B&B trees in the spring.

We found no size related differences with shrubs in gravel beds, both in their CGB suitability ratings and their transplant ratings.

Mulch matters. Regardless of the season of planting out CGB trees and shrubs, mulching the area over the root systems is critical to their transplant success. In particular, earlier in the summer (helps retain moisture) and later in the autumn (helps retain soil warmth) are the times when mulching is absolutely critical. Two to four inches of any mulch (not piled up on plant stems) is money smartly invested.

6.3 Species performance. The results of 15 years of research on species suitability and transplant success at the University of Minnesota is located in the **Appendix.** Use this as a guide, not as the final word. All data were collected in the upper Midwest where the summers are hot and rainfall unpredictable, and the winters are very cold and snowfall is equally unpredictable. Communities located in a more tempered cold hardiness zone, such as zones 5-9, are likely to experience higher transplant ratings as long as the plants are watered throughout the growing season.

Part 7: Managing the community gravel bed

7.1 Cost of CGBs. Cost is variable due to the variability of gravel bed designs, sizes of beds, and material costs in different regions. Having said that, the cost of pea gravel is usually the greatest expense, based largely on the distance from the CGB to the nearest quarry.

If the CGB is a simple pile of gravel on an old parking area, and the community has a ready supply of pea stone, then costs will be minimal if anything. As stated earlier in this guide, simpler is better…and more affordable. Architecturally pleasant CGBs are nice and draw positive community comments, but they have no influence on the way trees and shrubs perform in gravel and subsequently survive the transplant phase.

7.2 Providing water. Again, it is difficult to predict the frequency of irrigation on different gravel beds, the amount of water provided over the weeks the beds are in use, or the cost of water in various communities vs. well water. The major variables that influence watering needs are 1) wind exposure, and 2) sun exposure.

CGBs in full sun and windy sites will use much more water than those set up in shady and wind-protected areas. In the upper Midwest, there are CGBs that have irrigation cycles that run for 15-20 minutes on six hour cycles, 10 minutes on four to six hour cycles, or once a day for 15 minutes. In one rainy summer in western Minnesota, there was a CGB where irrigation was never turned on.

Simpler is better. Irrigation systems range from soaker hoses running the length of tree rows in a CGB to pop-up irrigation heads regulated by timers and computer settings – one is affordable, the other is expensive. Both work well as long as the moisture content of the gravel is monitored.

There are moisture sensors that can be installed to monitor moisture levels in the root zones (expensive), or fingers and hands (relatively inexpensive) can probe down through those 4-6 inches of gravel to determine whether or not the frequency and dose of water is adequate or needs to be adjusted. When possible, an irrigation system should be designed that can readily be shut down if the community is experiencing a rainy weather period.

One piece of "technology" that is worth the investment is an irrigation timer. These can be preset for the cycle (e.g., every 6 hours) and dose (e.g., 15 minutes) for the irrigation system. These timers are generally inexpensive (under $50) and can be purchased from most hardware or home improvement stores.

By far the simplest method of irrigating trees in a gravel bed, the “armstrong” method. If a community has a dedicated team of responsible volunteers that can reliably follow an irrigation schedule, this works well. Photo credit: A. Dierich.

Soaker hoses are very popular with communities, inexpensive, and very frugal water users. This system is regulated by an inexpensive timer. Photo credit: J. Wahls.

A slightly more elaborate system with buried poly hose lines with sprinkler heads. This system is very inexpensive to set up. Photo credit: A. Dierich.

A similar system with the poly hose above ground and inexpensive spray heads. This is a very flexible system where holes are drilled wherever necessary and the flexible tubing leading to the spray heads are installed in the holes. When these systems break down, they are very easy and inexpensive to repair.

A simple system with overhead sprinklers attached to tripods high enough to get even coverage of the trees in the bed. A system like this sacrifices the efficient use of water for the ease of set-up. If the useful life of the CGB is known to be short, this works well.

Inexpensive spray heads attached to fence posts in the bed with a garden hose supplying the water.

If the community wants to invest in more technology, this system monitors gravel bed moisture levels and temperatures, and triggers the frequency and dose of irrigation water through a computerized irrigation program. Theoretically, this system is more reliable. It's also expensive. In colder regions of the country, do not leave this equipment in the beds during winter months…they break. Hard lesson learned. Photo credit: A. Dierich.

7.3 Weed management. Weeds in a gravel bed bother people, not the trees or shrubs. If the unsightly appearance of a weedy CGB is an issue, the weeds are easily pulled by hand. The use of herbicides in gravel beds is discouraged because those chemicals are rapidly flushed through the bed and either into the groundwater system or surface waters.

7.4 Nutrient management. Community gravel beds are intended to be holding areas for plants, not production beds. The addition of nutrients such as nitrogen, phosphorus, and potassium is generally discouraged because gravel has no capacity to hold onto nutrients. Synthetic, fast-release fertilizers are flushed through as fast as a toilet flushing.

Two studies at the University of Minnesota examined adding nutrients and found that adding fast-release fertilizers had no visual or root growth effect on trees or shrubs. Adding slow and extended release fertilizers did promote more root growth, but there was no difference in the transplant ratings of any of the 18 species tested.

7.5 Disease management. In 15 years of research at the University of Minnesota, no issues with tree or shrub diseases were attributed to the gravel. If irrigation systems are ground level, such as the soaker hoses or low height sprinkler heads, no foliar leaf spot or anthracnose diseases occurred.

7.6 Insect management. There can be local infestations of some foliar feeding insects (e.g., Japanese beetles), but the occurrence and damage has been neglible. If defoliation is a potential issue, then insect infestations must be kept to a minimum to retain the vitality of the CGB plants, possibly via insecticidal sprays.

7.7 Animal damage. Animal damage such as deer and rabbit browsing, and ground squirrel damage to young stems can be a significant problem. Exclusionary fencing is the most effective method to prevent this type of damage in a humane way. Tightly knitted chicken wire fencing keeps rabbits and fat ground squirrels away from the plants, as well as deer. If ground squirrels or voles are problematic, the fencing needs to be ¼” hardware cloth.

Most animal damage to CGB trees and shrubs will occur during the spring and autumn weeks, and the worst occurs during the winter months. For that reason, it is recommended that all CGB plants be harvested and planted out before winter sets in.

Rabbit fencing such as this green coated wire product, is an effective barrier for larger mammals. For smaller and equally destructive animals such as trimmed-down streaky gophers (thirteen-lined ground squirrels) or voles, ¼" hardware cloth is the most effective barrier.

Chemical deterrants (olfactory sprays) are very effective at keeping gnawing and chewing animals away from tree and shrub stems, but they can be difficult to apply if the irrigation system is overhead. Ideally, a soaker hose system would be used to irrigate if these products are used. These olfactory materials need to be sprayed on the plant stems every four to five weeks for maximum effectiveness. Make sure you know which way the wind is blowing before spraying…another lesson learned the hard way.

Two of the very effective olfactory animal repellents. Make sure you know which way the wind is blowing before spraying on the gravel bed plants. For optimum effectiveness, these products should be applied every 4-5 weeks.

Appendix: Gravel Bed Species Performance Spreadsheet 2006-2020

Notes:

n = Total number of plants in the study.

Gravel Bed Suitability Rating is based on amount of fine root growth as well as foliage retention. It is a 1-5 scale with 1=poor, 2=fair, 3=good, 4=very good, 5=excellent.

Transplant Rating is based on survival and amount of dieback at the end of the growing season following transplanting. It is on a 1-5 scale with 1=less than 10% survival and living trees with uniform dieback; 2=10-25% survival with dieback on 25% of the trees; 3=25-50% survival with less than 25% of the trees with dieback; 4=75% or more survival and less than 10% of trees with dieback; 5=100% survival and little to no dieback. The numbers then correlate as 1=poor, 2=fair, 3=good, 4=very good, 5=excellent.

*Do not include 'Purple Robe' black locust in a gravel bed with other trees, and do not leave it in gravel for more than 8 weeks. It has an incredibly aggressive root system that takes over a gravel bed.

SCIENTIFIC NAME	COMMON NAME	n	SIZE	SUITABILITY RATING	TRANS-PLANT RATING	TRANSPLANT SEASON PREFERENCE
Abies balsamea var *phanerolepis*	Canaan fir	50	3-0 liners	Good	Good	Early Autumn
Acer x *freemanii* 'Jeffersred'	Autumn Blaze® maple	10	1.0" caliper	Excellent	Excellent	Summer thru Early Autumn
A. f. 'Bailston'	Matador™ maple	10	1.0" caliper	Excellent	Good	Summer thru Autumn
A. f. 'Marmo'	Marmo maple	20	1.5" caliper	Excellent	Excellent	Late Summer thru Early Autumn
A. platanoides	Norway maple	20	1.5-1.75" caliper	Good	Good	Summer thru Autumn
A. truncatum x *A. platanoides* 'Warrenred'	Pacific Sunset® maple	40	1.5-1.75" caliper	Fair to Good	Fair	Late Summer
A. rubrum	Red maple	20	1.5" caliper	Fair	Fair	Summer thru Early Autumn
A. saccharinum	Silver maple	20	1.5" caliper	Good	Good	Summer thru Early Autumn
A. s. 'Silver Queen'	Silver Queen silver maple	10	1.0" caliper	Excellent	Good	Summer thru Early Autumn
A. saccharum	Sugar maple	20	1.5" caliper	Fair	Good	Summer thru Early Autumn
Aesculus glabra	Ohio buckeye	25	5-6' branched	Fair	Good	Autumn
A. glabra	Ohio buckeye	30	1-0 seedlings	Fair	Excellent	Autumn
Alnus glutinosa	European black alder	20	1.25" caliper	Excellent	Excellent	Early Autumn
A. hirsuta 'Harbin'	Prairie Horizon® alder	20	1.25" caliper	Excellent	Excellent	Early Autumn
Amelanchier canadensis	Serviceberry	30	2-3' branched	Fair	Good	Early Autumn
A. x *grandiflora* 'Autumn Brilliance'	Autumn Brilliance serviceberry	5	5-6' branched	Excellent	Excellent	Late Summer thru Early Autumn
A. laevis	Serviceberry	7	6-7' branched	Very Good	Very Good	Late Summer thru Early Autumn
Aronia melanocarpa	Black Chokeberry	30	18-24" branched	Excellent	Excellent	Summer thru Early Autumn
Betula nigra	River birch	30	5-6' branched	Fair	Fair	Late Summer thru Early Autumn
B. nigra	River birch	60	2-3' 2-0 seedlings	Excellent	Excellent	Late Summer thru Early Autumn
B. nigra	River birch	75	1-0 seedlings	Excellent	Excellent	Late Summer thru Early Autumn

B. nigra 'Cully''	Heritage® River birch	5	1.5" caliper	Excellent	Excellent	Late Summer thru Early Autumn
B. papyrifera	Paper birch	35	1.0" caliper	Good	Good	Late Summer thru Early Autumn
B. p. 'Varen'	Prairie Dream® birch	20	1.0" caliper	Good	Good	Late Summer thru Early Autumn
B. platyphylla 'VerDale'	Prairie Vision™ birch	20	1.0" caliper	Good	Good	Late Summer thru Early Autumn
B. populifolila 'Whitespire'	Whitespire birch	20	1.0" caliper	Good	Good	Late Summer thru Early Autumn
Carpinus caroliniana	Blue Beech	10	5-6' branched	Excellent	Excellent	Late Summer thru Early Autumn
Carya cordiformis	Bitternut hickory	25	3-4' lightly branched	Fair	Fair	Late Summer thru Early Autumn
Celtis occidentalis	Common hackberry	30	5-6' branched	Fair	Good	Autumn
C. occidentalis	Common hackberry	70	3-4' lightly branched	Very Good	Very Good	Autumn
C. occidentalis	Common hackberry	45	2-3' whips	Excellent	Excellent	Autumn
C. occidentalis	Common hackberry	40	18-24" whips	Excellent	Excellent	Autumn
Cercidiphyllum japonicum	Katsura tree	60	1.25" caliper	Excellent	Good	Late Summer thru Early Autumn
Cercis canadensis	Eastern redbud	15	1.25-1.5" caliper	Very Good	Very Good	Autumn
Cladrastis kentukea	Yellowwood	5	6-7' branched	Excellent	Excellent	Autumn
Cornus alternifolia	Pagoda dogwood	20	4-5' branched	Very Good	Very Good	Late Summer thru Early Autumn
C. amomum	Silky dogwood	50	2.5' branched	Excellent	Excellent	Late Summer thru Early Autumn
C. mas	Cornelian cherry dogwood	10	6-7' branched	Excellent	Excellent	Early Autumn
C. racemosa	Gray dogwood	45	2' branched	Excellent	Excellent	Late Summer thru Early Autumn
C. stolonifera	Redosier dogwood	20	2' branched	Excellent	Excellent	Late Summer thru Early Autumn
C. r. 'Jade'	Snowmantle® gray dogwood	20	2' branched	Excellent	Excellent	Late Summer thru Early Autumn
C. sericea	Redosier dogwood	30	2' branched	Excellent	Excellent	Late Summer thru Early Autumn
Corylus americana	American hazelnut	15	2' branched	Excellent	Excellent	Autumn
C. avellana 'Jefferson'	Jefferson hazelnut	20	1.0" caliper	Good	Excellent	Autumn

C. colurna	Turkish filbert	15	2-3' whips	Very Good	Very Good	Late Summer thru Autumn
C. colurna	Turkish filbert	5	7-8' branched	Very Good	Excellent	Late Summer thru Autumn
Crataegus crus-galli 'Cruzam'	Crusader® cockspur hawthorn	15	1.25" caliper	Very Good	Excellent	Late Summer thru Autumn
C. mollis	Downy hawthorn	15	2-3' whips	Poor	Poor	Unknown
C. phaenopyrum	Washington hawthorn	15	2-3' whips	Poor	Poor	Unknown
C. x mordenensis 'Toba'	Toba hawthorn	5	6-7' branched	Good	Good	Late Summer thru Early Autumn
Eucommia ulmoides	Hardy rubber tree	20	1.5" caliper	Excellent	Good	Late Summer
Fraxinus mandshurica	Manchurian ash	45	2-3' whips	Excellent	Excellent	Late Summer thru Early Autumn
F. mandshurica	Manchurian ash	45	3-4' whips	Excellent	Excellent	Late Summer thru Early Autumn
F. mandshurica	Manchurian ash	85	4-5' lightly branched	Excellent	Excellent	Late Summer thru Early Autumn
Ginkgo biloba	Ginkgo	5	1.5" caliper	Excellent	Excellent	Late Summer thru Early Autumn
Gleditsia triacanthos var. *inermis*	Thornless honeylocust	45	3-4' whips	Excellent	Excellent	Late Summer thru Early Autumn
G. t. var *inermis* 'Harve'	Northern Acclaim® honeylocust	5	1.5" caliper	Excellent	Excellent	Late Summer thru Early Autumn
Gymnocladus dioicus	Coffeetree	30	3-4' whips	Excellent	Excellent	Late Summer thru Early Autumn
G. dioicus	Coffeetree	30	2-3' whips	Good	Good	Late Summer thru Early Autumn
G. dioicus	Coffeetree	10	1.25" caliper	Excellent	Excellent	Late Summer thru Early Autumn
G. dioicus 'Bravo'	Bravo coffeetree	15	2-3' whips	Good	Good	Late Summer thru Early Autumn
Juglans nigra	Black walnut	20	2-3' whips	Good	Good	Autumn
Larix laricina	Tamarack	70	1-0 seedlings	Excellent	Excellent	Autumn
L. laricina	Tamarack	30	2-0 seedlings	Excellent	Excellent	Autumn
Liriodendron tulipifera	Tulip poplar	10	1.5" caliper	Good	Good	Late Summer thru Early Autumn
Maackia amurense	Amur maackia	30	2-3' whips	Good	Good	Autumn
M. amurense 'Starburst'	Starburst Amur maackia	10	5-7' heavily branched	Very Good	Very Good	Late Summer thru Early Autumn

M. amurense 'Starburst'	Starburst Amur maackia	10	2-3' whips	Good	Good	Autumn
Malus species	Crabapple	30	4-5' branched	Excellent	Excellent	Autumn
Malus sp. 'Donald Wyman'	Donald Wyman crabapple	10	5-6' heavily branched	Excellent	Excellent	Autumn
Metasequoia glyptostroboides	Dawn redwood	10	6-7' heavily branched	Excellent	Excellent	Late Summer thru Early Autumn
Ostrya virginiana	Ironwood	10	6-7' heavily branched	Excellent	Excellent	Late Summer thru Autumn
Phellodendron amurense 'His Majesty'	His Majesty cork tree	20	5-6' branched	Fair	Fair	Late summer thru Early Autumn
P. amurense 'Macho'	Macho cork tree	20	5-6' branched	Fair	Fair	Late Summer thru Early Autumn
Physocarpus opulifolius	Common ninebark	30	2-3' whips	Excellent	Excellent	Late Summer thru Autumn
Picea abies	Norway spruce	40	1-0 seedlings	Fair	Good	Late Summer thru Autumn
P. glauca var. *densata*	Black Hills spruce	40	2-0 seedlings	Good	Good	Late Summer thru Autumn
Pinus ponderosa	Ponderosa pine	80	2-0 seedlings	Good	Good	Late Summer thru Autumn
P. resinosa	Norway pine	30	2-0 seedlings	Good	Good	Late Summer thru Autumn
P. strobus	Eastern white pine	45	2-0 seedlings	Excellent	Excellent	Late Summer thru Autumn
Platanus x acerifolia 'Morton Circle'	Exclamation!™ London plane- tree	30	1.25" caliper	Good	Very Good	Late Summer thru Autumn
Platanus x acerifolia 'Bloodgood'	Bloodgood London planetree	10	1.75" caliper	Very Good	Very Good	Late Summer thru Early Autumn
P. x acerifolia 'Bloodgood'	Bloodgood London planetree	5	1.25" caliper	Very Good	Very Good	Late Summer thru Early Autumn
Populus deltoides	Eastern cottonwood (male)	40	5-6' whips	Good	Excellent	Late Summer thru Autumn
P. deltoides	Eastern cottonwood (male)	20	1.0" caliper	Good	Excellent	Late Summer thru Autumn
Prunus americana	American plum	30	2-3' liners	Excellent	Excellent	Late Summer thru Autumn
P. americana 'Prairie Red'	Prairie Red American plum	30	2-3' liners	Excellent	Excellent	Late Summer thru Autumn
P. cerasifera 'Newport'	Newport plum, Minnesota strain	10	1.25" caliper	Excellent	Excellent	Late Summer thru Autumn
P. maackii	Amur chokecherry	40	2' liners	Excellent	Excellent	Summer and Autumn
P. tomentosa	Nanking cherry	25	2-3' liners	Excellent	Excellent	Summer and Autumn

P. sericea	(none)	15	2-3' liners	Excellent	Excellent	Summer and Autumn
P. serotina	Black cherry	40	2-3' liners	Excellent	Excellent	Summer and Autumn
P. virginiana	Chokecherry	25	2-3' liners	Excellent	Excellent	Summer and Autumn
Pyrus ussuriensis	Ussurian pear	30	3' branched	Good	Excellent	Autumn
P. u. 'Mountain Frost'	Mountain Frost Ussurian pear	15	6-7' branched	Excellent	Excellent	Autumn
P. u. 'MorDak'	Prairie Gem™ Ussurian pear	15	6-7' branched	Very Good	Excellent	Autumn
Quercus alba	White oak	20	5-6' branched	Poor	Poor	Autumn
Q. alba	White oak	30	3' branched	Good	Very Good	Autumn
Q. alba	White oak	30	1-0 liners	Excellent	Excellent	Autumn
Q. ellipsoidalis 'Bailskies'	Majestic Skies™ Northern pin oak	30	5-6' heavily branched	Fair	Good	Autumn
Q. macdanielii 'Clemons'	Heritage® oak	10	1.25" caliper	Fair	Good	Autumn
Q. macdanielii 'Clemons'	Heritage® oak	10	6-7' branched	Fair	Good	Autumn
Q. macrocarpa	Bur oak	20	1.5" caliper	Poor	Poor	Autumn
Q. macrocarpa	Bur oak	45	1.25" caliper	Poor	Poor	Autumn
Q. macrocarpa	Bur oak	30	3' branched	Good	Very Good	Autumn
Q. macrocarpa	Bur oak	20	18-24" liners	Excellent	Excellent	Autumn
Q. macrocarpa	Bur oak	40	1-0 liners	Excellent	Excellent	Autumn
Q. rubra	Red oak	30	5-6' heavily branched	Poor	Poor	Autumn
Q. warei 'Long'	Regal Prince® oak	10	5' heavily branched	Fair	Good	Autumn
Rhus typhina	Staghorn sumac	45	2-3' liners	Excellent	Poor in summer, Excellent in Autumn	Autumn
Rhus glabra	Smooth sumac	30	2-3' liners	Excellent	Poor in summer,	Autumn

					Excellent in Autumn	
Rhus trilobata	Skunkbush sumac	25	2-3' liners	Excellent	Poor in summer, Excellent in Autumn	Autumn
Robinia pseudoacacia 'Purple Robe'*	Purple Robe black locust	10	1.75" caliper	Excellent	Excellent	Late Summer thru Early Autumn
Salix babylonica	Weeping willow	10	1.5" caliper	Excellent	Excellent	Late Summer thru Early Autumn
Salix amygdaloides	Peach leaf willow	30	4-5' whips	Good	Good	Autumn
S. amygdaloides	Peach leaf willow	80	2' liners	Excellent	Excellent	Autumn
Sallix matsudana 'Golden Curls'	Golden Curls willow	5	1.5" caliper	Excellent	Excellent	Autumn
Shepherdia argentea	Silver buffaloberry	20	18-24" liners	Good	Good	Late Summer thru Autumn
Sorbus americana	American mountain-ash	60	2-3' whips	Good	Good	Late Summer thru Autumn
Syringa pekinensis 'SunDak'	Copper Curls® tree lilac	20	5-6' branched	Excellent	Excellent	Late Summer thru Autumn
S. p. 'Zhang Zhiming'	Beijing Gold® tree lilac	15	1.25" caliper	Fair to Good	Excellent	Late Summer thru Autumn
S. reticulata	Japanese tree lilac	30	3-4' branched	Excellent	Excellent	Late Summer thru Autumn
S. vulgaris	Common lilac	60	2' whips	Excellent	Excellent	Late Summer thru Autumn
Thuja occidentalis	Northern white cedar	45	3-0 liners	Excellent	Excellent	Summer thru Autumn
Tilia americana 'Bailyard'	Frontyard® linden	10	6-7' branched	Excellent	Excellent	Autumn
T.a. 'Boulevard'	Boulevard linden	20	1.75" caliper	Very Good	Very Good	Autumn
T. a. 'Redmond'	Redmond American linden	30	1.25" caliper	Good	Good	Late Summer thru Autumn
T. cordata	Littleleaf linden	30	1.25" caliper	Fair	Fair	Late Summer thru Autumn
T. tomentosa	Silver linden	15	1.75" caliper	Poor	Poor	Unknown
Ulmus americana 'American Liberty'	American Liberty elm	20	3-4' liners	Good	Good	Late Summer thru Autumn
U. americana 'New Horizon'	New Horizon elm	20	1.0" caliper	Excellent	Excellent	Late Summer thru Autumn

U. americana 'Prairie Expedition'	Prairie Expedition elm	20	1.0" caliper	Excellent	Excellent	Late Summer thru Autumn
U. americana 'Princeton'	Princeton elm	20	1.0" caliper	Excellent	Excellent	Late Summer thru Autumn
U. americana 'Saint Croix'	Saint Croix elm	30	1.0" caliper	Good	Good	Late Summer thru Autumn
U. americana 'Valley Forge'	Valley Forge elm	30	1.0" caliper	Good	Good	Late Summer thru Autumn
U. davidiana var. *japonica* 'Discovery'	Discovery elm	20	1.0" caliper	Excellent	Excellent	Late Summer thru Autumn
U. d. var. *japonica* 'Morton'	Accolade™ elm	20	1.0" caliper	Excellent	Excellent	Late Summer thru Autumn
U. x 'Frontier'	Frontier elm	72	1.0" caliper	Excellent	Good	Late Summer thru Early Autumn
Viburnum dentatum	Arrowwood viburnum	82	2-3' liners	Excellent	Excellent	Late Summer thru Autumn
V. lentago	Nannyberry viburnum	60	2-3' liners	Excellent	Excellent	Late Summer thru Autumn
V. trilobum	American cranberrybush viburnum	45	2-3' liners	Excellent	Excellent	Late Summer thru Autumn
Zelkova serrata 'Green Vase'	Green Vase Zelkova	35	1.25" caliper	Good	Good	Late Summer thru Early Autumn
Z. serrata 'Musashino'	Musashino Zelkova	15	1.25" caliper	Good	Good	Late Summer thru Early Autumn

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