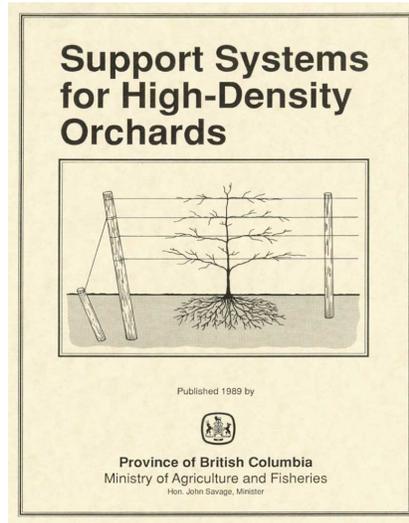


SUPPORT SYSTEMS for HIGH-DENSITY ORCHARDS (2018)



Ministry of
Agriculture

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Cover photo: Okanagan orchard with trellis support system

CONTENTS

- 1 Introduction..... 1**
 - 1.1 Benefits 1
 - 1.2 Trellises can Fail 1
 - 1.3 Costs of Failure 2
 - 1.4 Preventing Trellis Failure 2

- 2 Trellis Design..... 3**
 - 2.1 Posts..... 3
 - 2.2 Line Posts 3
 - 2.3 Single End Post..... 4
 - 2.4 H-Frame Posts..... 5
 - 2.5 Single Post with a Tie-Back Anchor 7
 - 2.6 Addition of an End-post to a Post with a Tie-Back..... 8
 - 2.7 Wire Spacing and Tension..... 10

- 3 Soil Considerations..... 10**

- 4 Trellis Components 12**
 - 4.1 Posts..... 12
 - 4.2 Wire 14
 - 4.3 Staples..... 15
 - 4.4 Wire Connection, Termination, and Tensioning 16
 - 4.5 Soil Anchors 17

- 5 Trellis Maintenance..... 18**

- Acknowledgements 19**

- Funding 19**

- Disclaimer 19**

- References..... 20**

1 Introduction

High-density dwarf tree fruit production is a common practice in BC orchards. The spindle-type tree is grafted or budded to a dwarf rootstock. These spindle-type trees produce fruit faster and at higher densities than traditional trees. The ability to quickly implement newer varieties that better meet market demands and improve financial returns make high density production attractive. However, the system has challenges. The limited branch framework of dwarf trees provides insufficient support for the crop, and hence a support system, also known as a trellis, is necessary for supplemental support.

1.1 Benefits

High-density orchards using trellises for support are initially more expensive to implement than traditional plantings but are more efficient and profitable over their production life. A trellis provides the following advantages:

- Encourages trees to put energy into fruit production instead of producing wood.
- Provides a uniform structure for tree training, promoting uniform growth.
- Improves light interception and uniformity of fruit quality and ripening.
- Produces earlier yields, potentially within two years of planting, and higher total yields over the life of the orchard.
- Reduces labour costs and encourages more uniform pruning, training, and thinning.
- Reduces damage to fruit and grafts by reinforcing trees against the wind.
- Facilitates the management of orchards as fruiting walls in two dimensions.

They also facilitate emerging technologies such as increased automation and mechanization to enhance productivity, quality, and efficiency. Trellises can also be used to cover the orchard with netting to protect the fruit.

1.2 Trellises can Fail

Trellises can fail. Figure 1 illustrates why. To be successful, a trellis must stand for the full life of the planting, typically 20 years. During this time, the capacity of the trellis system must always be greater than the load they are required to carry.

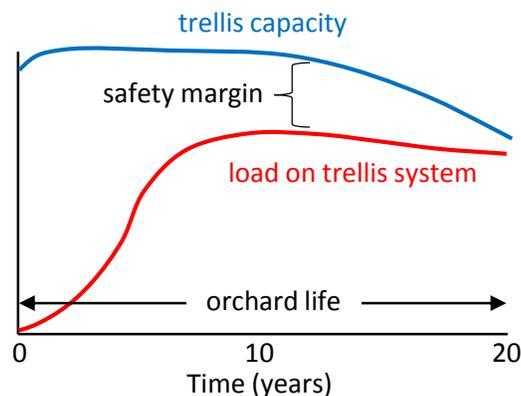


Figure 1 Evolution of trellis loads and trellis capacity over the life of the orchard.

It is important to recognize that the loads on and the capacity of a trellis change over the life of the planting.

- In the first two to three years, loads are relatively light as the planting establishes itself. At the same time, the trellis system is at its maximum strength.
- As trees grow and produce more fruit, typically from years five to eight, they exert a greater weight on the trellis and wind loads increase with greater foliage. Meanwhile, the trellis may begin to weaken due to:
 - Post rot where wooden posts enter the ground.
 - Corrosion of wire and hardware.
 - Cyclic wind loads, weakening posts, wire, connectors, and soil.
 - Operational wear and tear.
- After eight to ten years, loads may stabilize and slightly decrease on the trellis as spindles thicken and carry a bit more load, but the trellis system will potentially lose significant load capacity as a result of advancing post rot, and corrosion and fatigue of wire and metal.

If the loads on the trellis exceed the capacity of the trellis, it will fail.

1.3 Costs of Failure

Trellis failures can be costly. These costs can include:

- Reduced crop production directly from failure site itself and indirectly in opportunity costs.
- Lower crop quality from damage (e.g., bruising).
- Time, materials, and labour required to repair or mitigate damage.

Failure also means the loss of potential to implement new technologies and methods in the future to improve production and profits.

1.4 Preventing Trellis Failure

A properly functioning trellis is the product of good planning and implementation. Each support system must be uniquely designed for its site and application. It should not be assumed that the design of a support system on a neighboring orchard is adequate for the current application.

At the time of planting, the materials and construction that comprise a support system are near their peak performance, but experience minimal loads.

To overcome the challenges posed to support systems during their operational life and to mitigate failure, orchardists must use:

- A support system designed to provide adequate strength and resilience for its service life.
- Recommended materials that meet the design requirements of the system.
- Proper construction techniques in implementing support systems.
- Best practices in the use and maintenance of the support system over its service life.

This manual will guide producers in design and construction of trellises, the materials and methods used in their construction, and the expected costs.

Trellises must be designed and built for the full life of the orchard (20 years) to assure success. What may appear to be an overdesigned support system at the time of installation may only have a small safety margin for its capacity near the end of the orchard lifespan

2 Trellis Design

2.1 Posts

A trellis support system relies on posts and wires to support the weight of the trees and fruit, including wind loads. Larger posts installed at a greater depth create a stronger system. Not only is the post itself stronger but the lateral resistance to post overturning is higher because the forces acting on posts are distributed over a larger contact area. Increasing the post embedment in the soil will significantly increase the load capacity of the support system. The support system capacity is also dependant on the strength of the soil around the post.

The soil around driven posts will provide more resistance to wire and wind loads compared to a post installed in an auger borehole. Therefore, drive the posts where possible because a driven post can be 50% stronger than an augered posts. Driving posts is done most effectively by using a hydraulic post driver.

The support posts are typically installed in a straight line. The posts at each end of the line (end-posts) will carry more load than the posts within the line of posts (line-posts). The end-posts are designed differently than the line-posts. The designs presented here consider a recommended standard for line-posts and different design options for the end-posts.

The recommended post diameters presented in this manual refer to the **minimum diameter** of the post. For example, a 4” post can range up to 5” in diameter. The larger posts should always be selected and used for the end-posts.

2.2 Line Posts

The recommended design for a line-post is shown in Figure 2.

The recommended post is 12’ long and 4” in diameter. The recommended spacing between line posts is 30’ (10 m).

The post spacing should be reduced wherever the trellis goes over rises or dips in the land, or if the line of posts along a trellis has a slight bend.

Each post should be driven 3’ into the ground. The 12’ long posts can hold the top wire nearly 9’ above the ground. The recommended post size, depth of placement, and spacing are based on:

- **Post strength.** A 4” diameter post may seem excessive in the first years of establishing a new orchard. However, there is real potential for post rot, even with pressure-treated wood to the CSA O80 standard. Posts used in orchards and vineyards are often subject to regular applications of irrigation water, and despite no visible evidence of rot, a loss of 50% of a post’s strength is possible in the ‘rot zone’ over the 20-year life of the orchard. Furthermore, the ‘rot zone’ portion of the post is also subjected to the greatest forces.
- **Soil strength.** The soil strength varies with soil texture and density. The 30’ recommended spacing is based on calculations using the Trellx tool for sandy-gravel soils, which are common in the tree fruit growing regions of BC. However, there are soils with higher clay content in BC, and these can be weaker, especially under wet conditions. In these situations, post spacing should be reduced, or longer posts (14’) should be used and driven deeper.

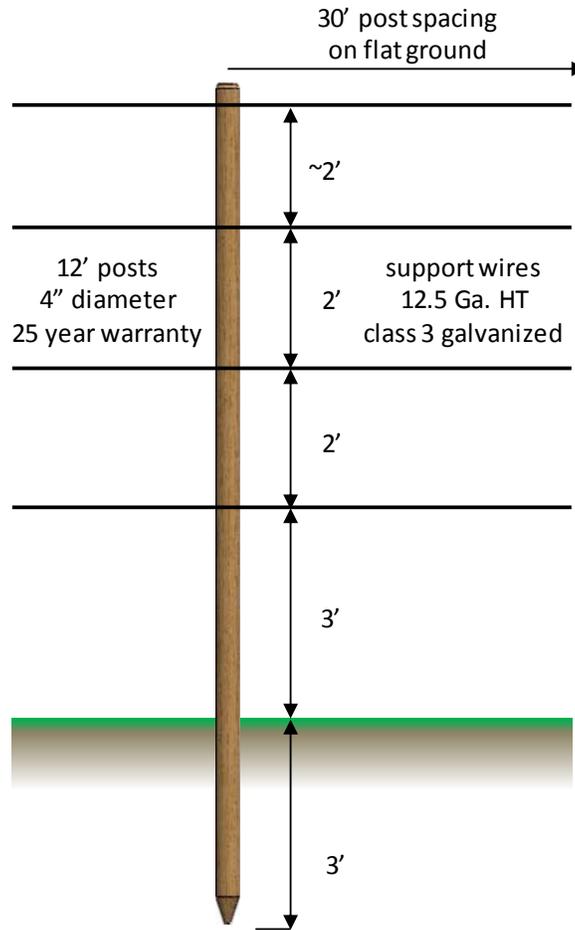


Figure 2 Recommended line-post wire spacing and embedment depth.

- Wind speed. The 30' spacing is based on the trellis experiencing a wind speed of 50 km/h (30 mph) with a full fruit wall typical of the late summer and early fall (August to October). However, historical data have shown that gusts of wind up to and greater than 75 km/h (45 mph) can occur during this same period. Calculations using the Trellx tool indicate that with winds of 80 km/h, the same 12' by 4" posts at the 3' depth should be spaced less than half the distance apart (15').

Finally, if the posts are also used to hold netting over the trees, then longer (16') posts should be used to provide sufficient height.

2.3 Single End Post

The simplest end-post design is a single post that has a larger diameter and deeper depth of embedment than the line-posts. If the trellis is used in soil conditions that have relatively high strength, then a single end-post as illustrated in Figure 3 should be sufficient.

The single end-post is the simplest but also the weakest design. The loads in the trellis wires terminate at the end-post and thus pull the end-post towards the line-posts. The soil around the post resists this load. The post itself also has a bending resistance to the wire loads.

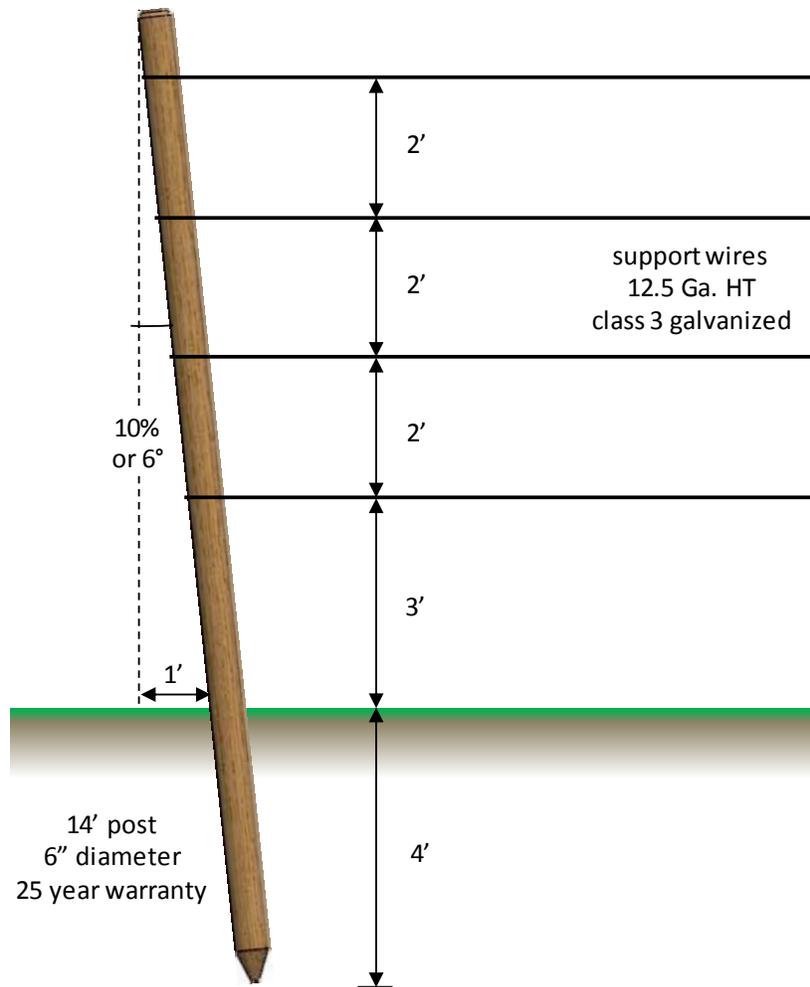


Figure 3 End-post consisting of a 6" post embedded deep into the ground.

The recommended post is 14' long and 6" in diameter. Each post should be embedded 4' into the ground. The post should be pounded into the ground at a slight angle 10:1 (ratio between vertical distance and horizontal distance) as shown in Figure 3. This also translates into a 10% or 6° lean off of vertical. The larger post diameter and deeper embedment are essential to handle the bending loads that will be placed on the post by the wires.

A single end-post will likely move towards a vertical orientation over time as the loads increase in the orchard and fluctuate on the wires. The trellis wires should be re-tensioned if the post moves in the ground.

2.4 H-Frame Posts

The H-frame system uses two end-posts to effectively share the wire loads and transfer them to the soil. The recommended posts are 6" in diameter and at least 12' long. Each post should be driven a minimum of 3' into the ground. When the soil is weak, use 14' posts and embed them 4' deep to keep the top wire 9' above the ground as shown in Figure 4.

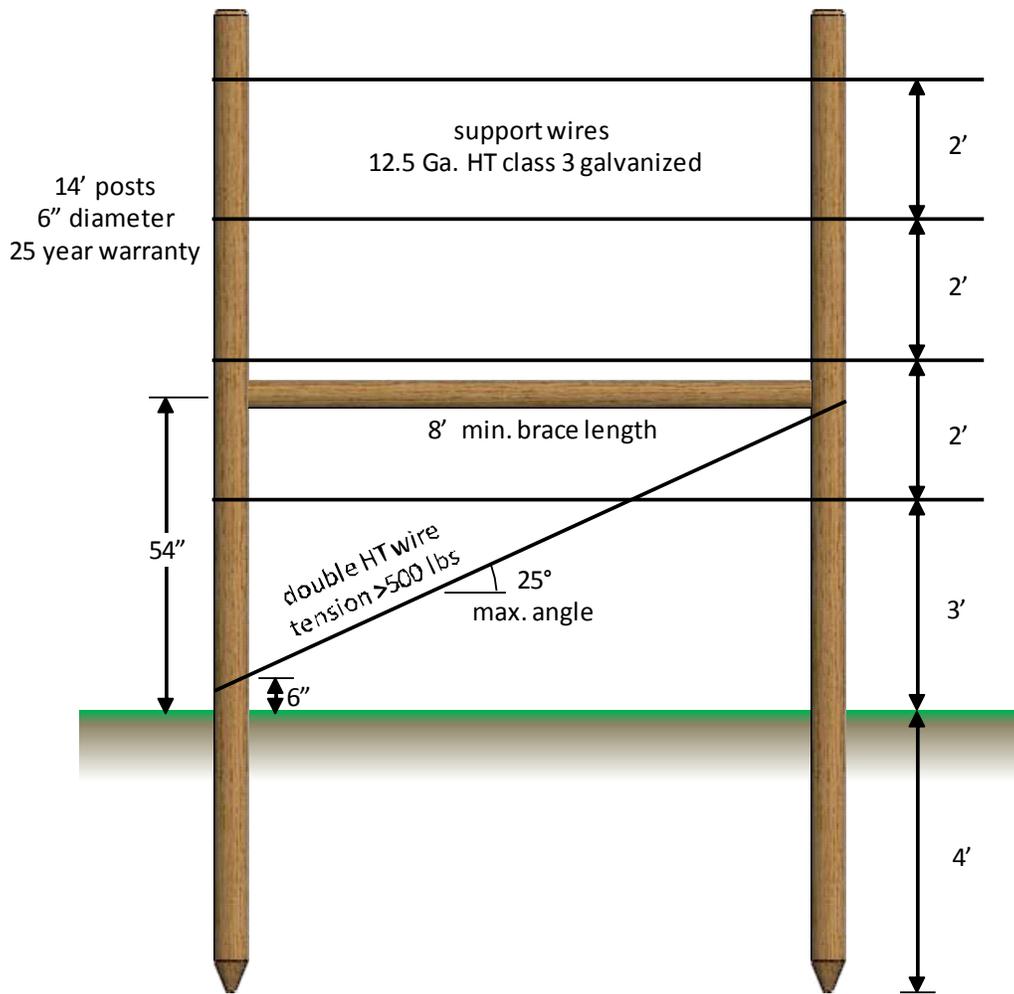


Figure 4 H-Frame end-post assembly.

The H-frame makes use of a horizontal cross-brace and a diagonal tension wire. The primary purpose of the brace and diagonal tension wire is to distribute and share the trellis wire loads between the two posts. This effectively doubles the holding capacity of the system versus a single post of the same diameter and installation depth, making this system superior to the single end-post design. Avoid notching posts. If posts are notched, treat with copper naphthenate to prevent rot.

The length of the posts above the brace will have sufficient capacity to withstand bending forces from the trellis wires. It is the length of the posts below the ground that is the critical feature of the H-frame system as this is where the soil must resist the over-turning of both posts.

The horizontal cross brace should be twice as long as the brace height above the ground. Most orchards that use the H-frame system have been installing the cross-brace unnecessarily high above the ground. The appropriate brace height is approximately 54" above the ground. This height also facilitates safer and easier installation. With a 54" installation height, the brace should be 9' long, although an 8' long brace can also be used. The purpose of the longer brace and lower brace height is to ensure that the diagonal tension wire is kept at a shallow angle

(<25°) to the ground. It is only the horizontal component of the tensile load in the diagonal wire that provides the thrust in the brace which helps the end post carry the wire loads.

The diagonal tension wire should be installed close to the ground at the end-post, but above the wet soil and vegetation. The opposite end of the diagonal tension wire is typically installed at the same height as the brace, although it can be installed slightly lower. The diagonal tension wire typically consists of 12.5 Ga. HT wire wrapped around both posts and tensioned to provide a continuous loop. Two loops of wire are recommended create an even stronger system. Thus the tension is carried by four wires between the posts. It is important to install the wire with a relatively high tensile load of approximately 500 lbs. The wires need to be secured with at least two staples to each post. Alternatively, lag bolts or nails can be used to keep the wires from slipping along the posts.

2.5 Single Post with a Tie-Back Anchor

In weaker soils, an alternative to the single end post design is one that uses a tie-back anchor (Figure 5). These anchors can transfer a significant portion the wire loads directly into the ground. The tie-back decreases the amount of effort required by the post and the soil surrounding the post to resist the wire loads. The loads on an unanchored end-post have leverage to bend the post and the soil out of the way much like a person would dig with a shovel. In contrast, failure of the soil anchor requires a direct pulling force that lacks the advantage of leverage. This provides a significant advantage over a simple one post design.

The recommended post is at least 12' long and 4" in diameter. The post should be driven at least 3' into the ground. By using a tie-back anchor, a smaller end-post will suffice compared to using a single end-post without one. The post should be installed with a 10:1 lean (vertical distance: horizontal distance). The top wire will need to be lowered to slightly less than 9' above the ground if a 12' long post is used and installed to the correct depth.

Install the soil anchor at least 8' away from the post. The required anchor depth will vary with soil conditions but should be at least 40" below the ground.

If a Gripple™ soil anchor (#4) is used, hammer the anchor into the ground at a slight angle (~20°) as shown in Figure 5. If a helical screw anchor is used, the helix diameter should be 5" to 6", and the steel shaft diameter should be at last 3/4". A smaller helix can be used in strong soils and a larger one in weak soils. In weaker soils, install the anchor as deep as possible.

The ground anchor should be connected to the end-post roughly 54" above the ground. A connection to the post higher than 54" will result in less load being transferred from the trellis wires to the anchor reducing the effectiveness of the tie back anchor in restraining the trellis wire loads. It is a common mistake to connect the soil anchor too high on the post and to place the soil anchor too close to the post.

A double-loop of 12.5 Ga. HT wire can be used to connect the tie-back post to the soil anchor. This wire should wrap around the post and run through a wire rope thimble at the soil anchor. This wire will form two continuous tensioned loops. Thus the loads are carried in four wires between the post and soil anchor. It is important to install the wire with a relatively high tensile load of approximately 500 lbs.

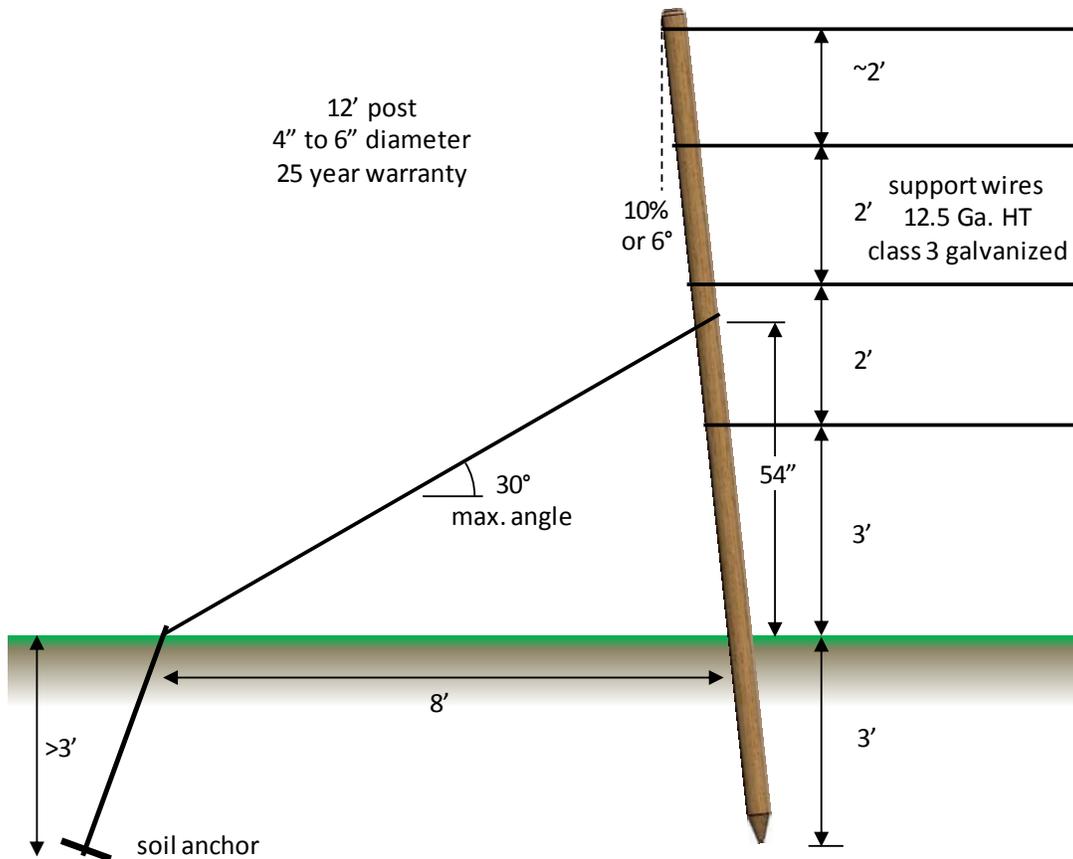


Figure 5 End-post with a tie-back soil anchor.

Alternatively, a 5/32" galvanized steel 7x19 cable can be used to connect the anchor to the post. The tension in this cable should be approximately 1000 lbs. A Gripple™ DPAK connector is very useful for completing the connection between the soil anchor and the post.

It is important to drive both the soil anchor and post to their full depths. If the soil strength is poor, the following options can be used:

- drive the anchor deeper
- use a bigger anchor
- drive the post deeper, or
- use a larger diameter post.

2.6 Addition of an End-post to a Post with a Tie-Back

One issue with using a tie-back anchor at the end of the line of posts is that the anchorage requires space that does not support trees and the anchorage impedes equipment travel around the end of the trellis. A solution to overcome these limitations is to use the tie-back on the second-last post along the trellis. In this manner, the anchorage does not get in the way of equipment, and the full length of the orchard can be used to grow trees. A further advantage of this end-post design is that the last post can also assist the tie-back post in carrying the trellis wire loads. This design uses fewer post materials compared to the H-frame system and can achieve greater capacity than an H-frame even when using smaller diameter posts. The greater capacity comes from the soil anchor that is added to the two posts to carry a portion of the load.

2.7 Wire Spacing and Tension

A trellis makes use of posts to carry the wires, which in turn support the trees and their fruit. A support system will typically use four high tensile strength (HT) wires strung between the posts. The recommended wire to use is 12.5 gauge HT, galvanized (Class 3) steel wire.

The recommended maximum vertical wire spacing is 2' with the lowest wire set approximately 3' above the ground. The top wire can be attached to the top of the post, but the recommended better practice is to attach it at least 4" from the top of the post. The lowest wire is also typically used to carry irrigation lines. It is important that the trellis wires be tensioned to 250 lbs after they are installed on the line of posts. The tension should be checked over the life of the trellis system and adjusted if needed. Slack in the wires will cause underperformance of the system.

If possible, the length of a trellis wire should be kept less 500' (150 m) to reduce end-post loads.

After the trellis is installed and the wires are stretched to the proper tension, a grounding wire should be installed for lightning protection.

3 Soil Considerations

The soil beneath an orchard ultimately supports the trees and the trellis system. It is extremely important to recognize the uniqueness of each orchard site. *“Just because a trellis design worked at your neighbour’s farm, doesn’t mean it will work at yours”* (Fraser 2017). Soils in BC have been mapped in many areas. Soil texture (see Figure 7), an important indicator of soil strength, can vary significantly within only a few hundred metres.

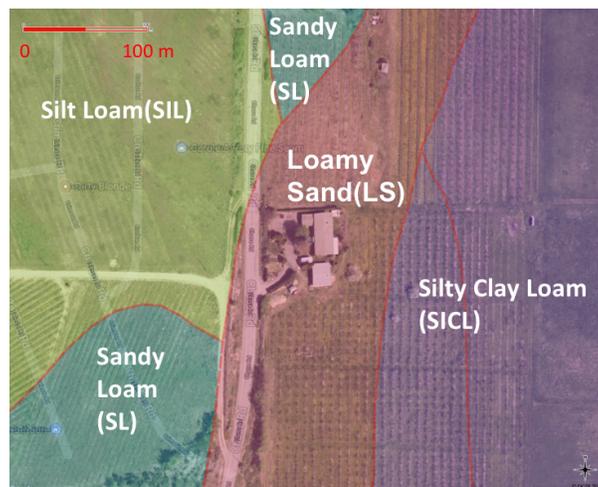


Figure 7 Typical soil texture map.

It is ultimately the soil beneath an orchard that determines the carrying capacity and required characteristics of a trellis system. Soils are classified by their three primary components: sand, silt, and clay (Figure 8).

- Weaker soils, with less strength, will require closer post spacing, greater post depths, and more complex end post systems.

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- Rocky soils may inhibit the placement of posts, and require complex end post systems.
- Soil strength increases with the degree of compaction and bulk density.
- Wetter soils tend to be weaker. Soils with significant clay content can be relatively strong but lose their strength when they become highly saturated.
- Poor drainage and moisture accumulation, especially in fine sand and silt soils can greatly reduce soil strength.
- Flatter topography reduces the required strength and integrity of support systems.

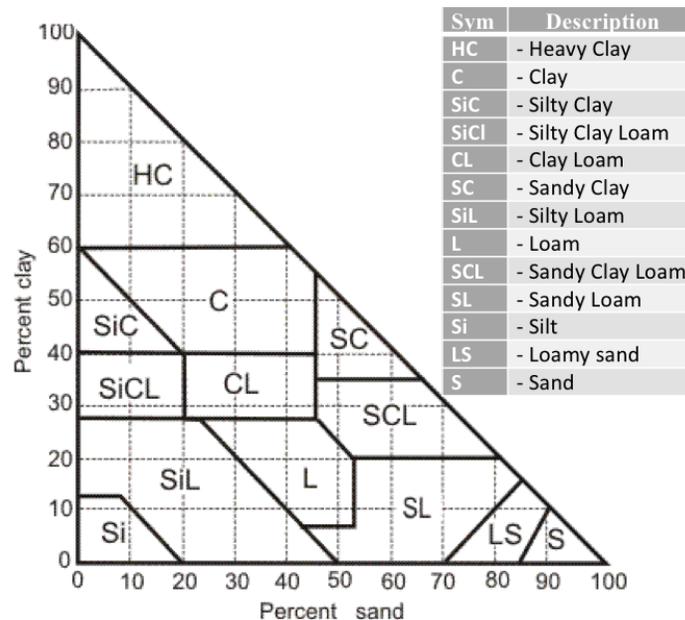


Figure 8 Soil textures.

Table 1 lists the expected range of soil strength represented by the maximum lateral pressure that can be applied to the side of a post, friction angle, and soil density. Approximate bearing capacities for soils are also listed, and these indicate the effort needed to drive a post into the ground. These properties can be used to estimate the required depths for wooden posts.

Table 1 Typical soil properties.

Soil type	Lateral pressure per unit depth (kPa/m)	Friction angle	Density (kg/m ³)	Bearing capacity (kPa)
Sandy gravel, and or gravel	31.4 -47.1	32° - 38°	1440 - 1760	100
Sand, silty sand, clayey sand, silty gravel, and clayey gravel	23.6 -31.4	26° - 31°	1360 – 1680	70
Clay, sandy clay, silty clay, and clayey silt	15.7 -20.4	12° - 25°	1440 - 1920	50

Soil properties should be measured on site before designing and implementing a support system.

4 Trellis Components

4.1 Posts

Posts are the ‘trunks’ of an orchard support system. Posts provide support to the trees, fruit, irrigation components, and to resist wind loads. They must last for the entire life of the planting, typically (20 years).

Steel or concrete posts can be used, but the most common posts used in BC are treated Lodgepole pine. Lodgepole pine posts have little taper and knots. Knots, splits, and high moisture content will reduce a post’s strength. Choose posts with minimal knots and cracks. Pre-select the best quality posts for end-posts. Pre-measure and mark posts for depth to ease installation.

It is important to understand that posts are sold in size ranges spanning one inch and by the minimum diameter. For example, a 4” diameter post has a minimum diameter of 4”, but over its length, the diameter can taper from 4” to 5”. The minimum post diameter should be 4” (100 mm).

The post diameter governs the load the post can withstand before it breaks. Figure 9 shows the maximum force that a Lodgepole pine post can carry at a distance of 7’ above the ground. The load capacity for a 6” post is 3.4 times higher than for a 4” post.

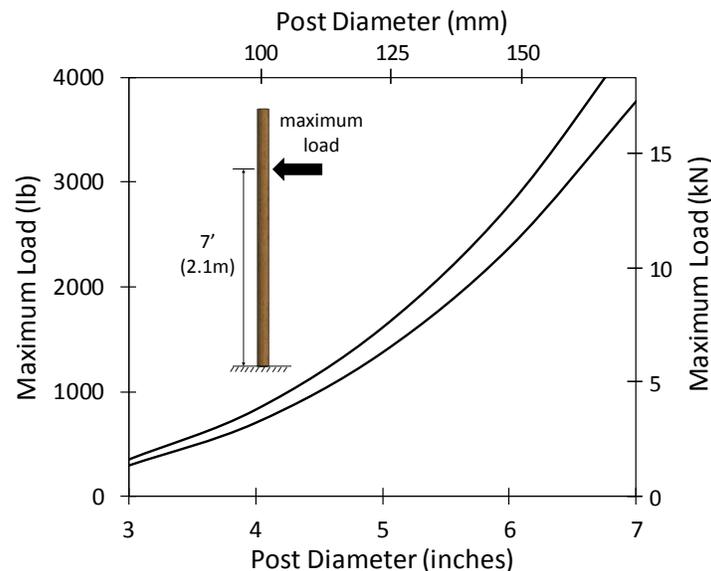


Figure 9 Upper and lower limits for the maximum force a Lodgepole pine post (12% moisture content) can withstand before breaking.

Using posts smaller than specified in a trellis can seriously increase the risk of failure over the life of the orchard (20 years).

The depth a post is embedded into the ground affects its resistance to over-turning by a force applied to the post. Using the same load location shown in Figure 9, the maximum allowable force before the post begins to over-turn for different embedment depths is shown in Figure 10. This figure illustrates the importance of the soil strength. Strong soils provide much higher over-

turning resistance than weak soils. A comparison between Figure 9 and Figure 10 shows that the post itself can typically handle the loads better than the soil. For example, a 4" line-post installed 3' into medium strength soil can be pushed over with a force of 3 kN, whereas the post itself can withstand 4 kN before it breaks. A single 6" end-post installed 4' deep will not over-turn until the load exceeds 6 kN, which is twice the value for a 4" post that is 3' deep. A 6" post will not break until the load exceeds about 12 kN. In these two examples, the soil is the limiting factor, not the post, which emphasizes the need to ensure the posts are driven deep enough into the ground.

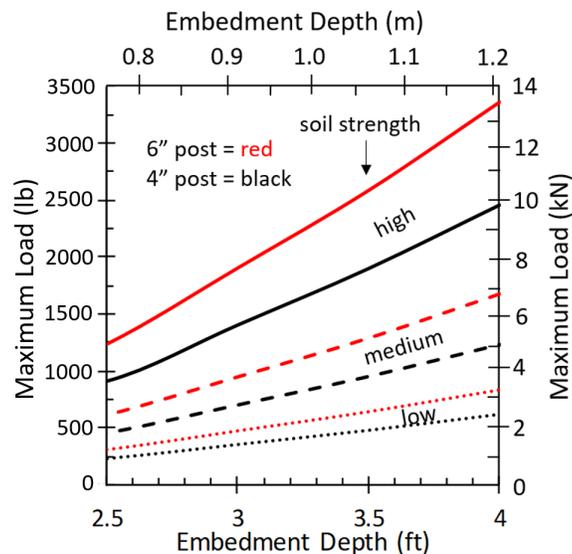


Figure 10 Maximum allowable force applied at 7' above the ground for a post installed at different depths in soils with different strengths.

The major disadvantage with wooden posts is their susceptibility to rot and fungal decay. Fungal rot destroys the cellulose in wood that provides its strength. Brown rot can reduce wood mass by 5 to 10% while being visually undetectable and reducing a post's strength by 20 to 80%.

Referring to the examples presented earlier in the comparison between Figure 9 and Figure 10, once the post experiences significant rot, the weakest component shifts from the soil to the post.

Wood maintained at less than 20% moisture will resist rot. Wood that is deep in the ground below the water table is less susceptible to rot due to low oxygen levels. The most critical location for post rot is slightly above and approximately 0.3 m below the ground surface (Figure 11), where optimum conditions occur for fungal growth and rot. This is also the location where the highest bending forces occur in the posts.

To maximize the life of a support system, the posts must be pressure treated with wood preserving chemicals. While treated wood costs slightly more, pressure-treated posts greatly reduce system maintenance and extend the support system life.

When purchasing pressure-treated posts, request posts that have been treated for 'ground contact' conditions. Specifically, the posts should be treated with Chromated Copper Arsenite (CCA) to the CSA O80 standard. Untreated Lodgepole pine posts have a life expectancy of only 4 to 12 years before being severely affected by rot. Cedar posts can be expected to provide 20 or more years of service without deterioration. When treated to the CSA O80 standard and subjected to

normal weather conditions with some exposure to freshwater, Lodgepole pine posts should be good for more than 25 years. If in doubt whether the posts have been treated to the standard, check the warranty provided by the supplier. Posts treated to the CSA O80 standard should be warranted for at least 25 years. Currently, CSA O80 pressure treated Lodgepole pine posts are available in diameters up to 8-9", nominally 8", and up to 39' in length.

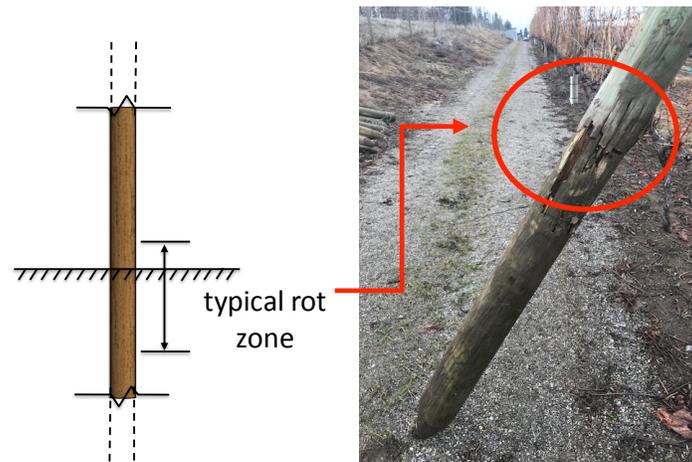


Figure 11 Rot zone for wooden posts.

If posts are cut during installation, the freshly exposed wood should be brushed with copper naphthenate. Allow one week for the treatment to dry before using the posts or for planting trees near the posts.

Certified organic standards do not currently permit the use of treated wood posts. In this case, cedar posts are recommended as an alternative. Note that Western red cedar has approximately 70% of the strength of Lodgepole pine. Thus larger 5 to 6" post diameters are recommended everywhere in a trellis system constructed with cedar posts.

4.2 Wire

The use of high tensile strength wires is the primary means of transferring loads from trees to posts via staples and fasteners. Wires carry the weight of the trees, the fruit crop, and anything attached to the trees or exerting forces on them, including wind. In BC, the commonly available wire for the construction of trellises for tree fruits and grapes include:

- 14 Ga galvanized in 5858 ft rolls (imported)
- 12 Ga galvanized in 3750 ft rolls (imported)
- 12.5 Ga galvanized in 3750 ft rolls (domestic)

It is **strongly recommended** that the 12.5 Ga (domestically produced) wire with Class 3 galvanizing be used. Research indicates this wire seldom breaks and relative additional cost to alternatives is negligible. This wire has a breaking strength of 1380 lbs and is ideal for orchard support systems because it provides adequate strength while minimizing exposure to corrosion over the life of the planting (20 years). In use, it should be tensioned to 250 lbs.

Class 3 galvanizing provides significantly more protection than Classes 1 and 2. Class 3 galvanizing is the preferred standard to provide long-term protection from corrosion. With this

corrosion protection, rust should not appear on the wire in the first 13 years under humid conditions, and it will take more than 50 years before the wire strength reduces by 50%.

When installing the wire, do not kink the wire as this weakens it. Carefully roll the wire off the rolls using a Spinning Jenny. Do not lay the roll of wire on the ground and pull the wire off the roll. If the wire is not removed from the roll opposite to the way it was rolled on, the wire will become distorted and may kink.

To make splices in HT wire, use 3 sleeves. Slide all 3 sleeves onto one wire. Thread the second wire to be spliced through the other side of the sleeves. Overlap wires so there is enough space on the wires for all 3 sleeves. Use a crimping tool to crimp the sleeves closed.

4.3 Staples

The trellis wires are typically connected to the posts with staples. Another option is to drill a 3/8" diameter hole through the posts at the desired height and run the wire through the holes.

Staples are available in different sizes, but 2" staples with double barbs, slashed ends and Class 3 galvanized coating should be used (Figure 12). They are only marginally more expensive than alternatives but provide greater penetration depth into posts and better holding capacity.

Staples should be driven such that a small gap remains between the trellis wire and the crown of the staple. This prevents kinking and strength loss in the HT wire. Leaving a slight gap also allows the wire to slide beneath the staple to better redistribute loads in the wire. Hold wires against the post when driving in staples to prevent damage to the wires. Staples should also be driven at an angle into the grain of the wood, not vertically (Figure 13).

For posts on top of a hill, the tension in the wire will pull the staples down, thus angle the staples slightly upward when driving them into the post. For posts in a low area, the wire will pull the staples upward, thus angle them downward. Use two staples for each wire in both cases.

If posts are drilled to pass the wire through, then ensure holes are drilled straight and level to minimize interference with the trellis wires. Posts with holes are not recommended for use in hilly ground where wires can pull up or down and cut into posts and weaken them.

Mount support wires on the windward side of posts to maximize support in windy conditions. There is no agreement on which side of supporting wires trees should be on. Trees on the windward side have more support and are more forgiving of tree connectors. Trees on the leeward side have less support but are also less subject to trunk bruising.



Figure 12 Double barbed galvanized staple.

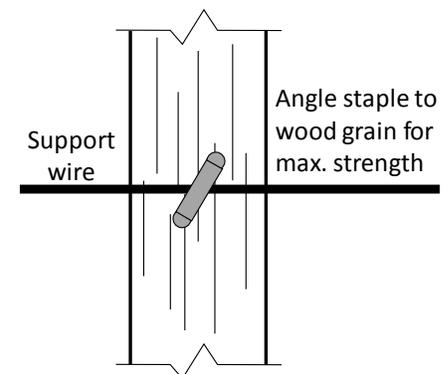


Figure 13 Drive staples at an angle to wood grain.

4.4 Wire Connection, Termination, and Tensioning

Supplemental hardware exists to ease the construction of an orchard support system, particularly in splicing and joining wires and in anchoring to the ground. Growers should refer to their suppliers for available supplemental hardware and should take the time and effort to ensure that they know how to properly and safely use the tools.

Each high tensile strength wire must be terminated at the end-post. Different options exist for terminating the wires. Twisting and tying the high tensile strength wire is not recommended as this can significantly reduce the tensile strength of the wire. The simplest termination option consists of using double-barrel wire crimp sleeves (Figure 14). The wire is inserted through two crimping sleeves and then wrapping twice around the post. The dead end of the wire is then inserted through the other half of the two crimping sleeves and crimped into place. This option does not permit for adjustment of the wire tension, and thus the wire will need to be tensioned and terminated differently at the other end, or an in-line wire tensioning device will need to be used.



Figure 14 High-tensile wire sleeve.

A ratcheting wire strainer (Figure 15) can be attached near the post to provide a wire tensioning when using crimping sleeves. The end of the ratchet is attached to the post using a loop of 12.5 gauge HT wire and two crimping sleeves. For a trellis length less than approximately 500', the ratcheting wire strainer only needs to be placed at one end of the wire run. If the trellis length is greater than 500', placing the ratcheting wire strainer in the middle of the wire run permits better tensioning over the full length of the trellis.



Figure 15 Ratcheting wire strainer.

For wire lengths less than roughly 250', an adjustable termination can be achieved by drilling a 3/8" diameter hole through the post, running the wire through the hole and then through a one-way steel wire vise (Figure 16). The locking portion of the vise is forced into the hole when the wire is tensioned. As long as a sufficient length of the wire remains protruding beyond the wire vise, this termination method allows for further tensioning if needed. Thus it is good practice to leave a small length of wire sticking out of the vise. Bend the end of the wire over and pushed into a small hole in the post or staple it to the post to safely hide the sharp end of the wire.



Figure 16 One-way wire vise.

An option for controlling the tension in long runs (>500') of wire is to use an in-line wire tensioner (Figure 17) placed roughly mid-way along the wire.

A quick and flexible termination option that allows for adjustable tensioning of the HT wire is the use of a medium size Gripple™ self-locking wire connector

(Figure 18). The HT wire is inserted through one opening in the connector and wrapped around the post, and the dead end of the wire is inserted through the second opening in the connector and tensioned. The connector should be spaced approximately 2' from the post. The wire can be re-tensioned if needed using the Gripple Torq tensioning tool. If the trellis length is greater than 500', it is best if a Gripple™ self-locking wire connector is used at both ends of the wire to ensure proper tensioning of the wire along the full run length.

Orchardists should also invest in a wire tensioning tool, for example, a Gripple Torq tensioning tool (Figure 19) can be used to assure proper tension is maintained in the trellis wires. This tool can apply up to 600 lbs tension in the wire.

4.5 Soil Anchors

The two general types of soil anchors can be used to secure tie-back wires/ropes (Figure 20). One type consists of a helical steel plate welded onto the end of a steel rod. The anchor is installed by applying a torque to the rod, which screws the helix into the soil. The other type consists of a harpoon-like device that is driven into the soil. The 'harpoon' is attached to a steel wire rope, and when the rope is placed under tension, the harpoon rotates within in the soil to lock the rope.

Both anchor types should be installed greater than 40" (1 m) into the ground. Ideally, each soil anchor should be installed in firm undisturbed soil at an inclination (see Figure 6) such that the wire rope or anchor shank to points towards the tie-back attachment location on the end port. The attachment loop should be near the ground surface after the anchor is installed.

Screw-in anchors should have a 5" to 6" (12.5 to 15 cm) diameter helix welded to a 3/4" (19 mm) diameter shaft with a heavy eye ring for the wire or rope attachment. A 6" diameter helix should have a holding capacity of 4000 lbs (20 kN) in most soil types.

A popular harpoon type soil anchor is the Gripple™ anchor. The larger #4 Gripple™ anchor should be used along with an anchor cable that is least 5/32" in diameter. A 5/32" galvanized steel 7x19 cable typically has a breaking load of approximately 2600 lbs. A #4 anchor should have a holding capacity of 1000 to 4000 lbs depending on the soil type.



Figure 17 In-line wire tensioner.



Figure 18 Medium size Gripple™ connector.



Figure 19 Gripple Torq tensioning tool.



Figure 20 Harpoon and screw type soil anchors.

A double-loop of 12.5 Ga. HT wire can be used to connect the tie-back post to the soil anchor. This wire should wrap around the post and run through a wire rope thimble or steel eye at the soil anchor. This wire will form two continuous tensioned loops. Thus the loads are carried in four wires between the post and soil anchor. It is important to install the wire with a relatively high tensile load of approximately 500 lbs. Alternatively, a 1/4" steel wire rope in a single loop can be used to connect the end post to the soil anchor.

5 Trellis Maintenance

Once installed and established, orchardists should periodically exercise maintenance to assure the integrity of the trellis system over its entire life. Ideally, the followed should occur annually:

- The tension in the trellis wire should be periodically checked and adjusted if necessary to maintain a load of 250 lbs (1.1 kN) when the wire is carrying fruit loads. The wire tension should be reduced before winter to accommodate thermal contraction of the wire under cold temperatures.
- Check for loose staples and add new ones as necessary, especially for hilly ground.
- Inspect the end posts to ensure they have not loosened or experienced unexpected rot. End posts should be replaced if they are damaged.
- Limit leader growth to 1' above the top wire to minimize breakage adversely affecting tree structure and performance. Annually, remove large side branches near the leader to avoid heavy crop loads above the top wire.

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