TRIAL MEASUREMENT MANUAL

BEST PRACTICES FIELD PROCEDURES FOR TREE MEASUREMENTS IN GENETIC FIELD TRIALS

Alberta Agriculture and Forestry
Alberta Tree Improvement and Seed Centre
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1. INTRODUCTION

Collecting and maintaining accurate data from genetic field trials is paramount in tree improvement programs. The collected data are the basis for generating information used to direct applied tree breeding, publish scientific papers and for determining increased annual harvest levels to be awarded to forest companies involved in provincial tree breeding projects. The data also represent a provincial heritage resource.

In recognition of the importance of the quality of genetic data, the Alberta Forest Genetic Resource Management and Conservation Standards (FGRMS), revised in 2016, set acceptable tolerances for measurement on height and diameter in field trials (FGRMS 30.10.2 through 30.10.5). Please ensure you take the time to review the appropriate FGRMS, the procedures and guidelines included in this document and collect the field data in a thorough manner. Failure to meet the standards and the subsequent need to re-measure field trials is very costly. Please note that a genetic test measurement report needs to be submitted to Alberta Tree Improvement and Seed Center (ATISC) together with checked raw data and quality control summary statistics (FGRMS 30.12.2).

The following guidelines and procedures for measurement of genetic field trials are not mandatory under FGRMS but represent best practices to ensure data quality standards required in the standards are met and the associated costs of poor information or requirement for corrective re-measurement of field trials is avoided. These best practices attempt to establish standard equipment and procedures that will assure accuracy and repeatability of measurements.

2. GENERAL GUIDELINES

- Test sites scheduled for measurement during a given measurement season should be visited before the measurements to check access roads and test conditions such as presence of excessive brush, large ingress trees or damaged trees that could be of potential hazard and would slow down the crew. At the same time test markers should be checked against the test map and improved, corrected or replaced as necessary.
- Growth traits should be measured in the dormant season.
- Crew training should not be done during the measurements. Each crew member must be thoroughly familiar with the electronic or paper-based recording system

and with measuring equipment such as the Vertex before the measurements start. Each crew member must understand the tree status scoring system and tree condition codes. It is a good practice to carry a sheet with the status and condition codes. In addition, crew members need to understand the test marking system and maps.

- Each day, prior to the start of measurements, safety procedures must be reviewed. Each crew member needs to have access to a communication device (a satellite phone or a cell phone if there is signal in the area) and access to a vehicle in case of emergency.
- It is a good practise to establish the same measuring sequence (typically a serpentine) in each replication and follow the same sequence in all subsequent measurements.
- The same team should measure the whole replication and each member of the team should have the same function within one replication. In this way any possible bias resulting from differences between individuals will be limited to the replication and thus accounted for in the statistical analyses. In addition, this can make the re-measurements more efficient if some replications fail the quality control.
- One crew member needs to carry the test map and be responsible for ensuring that the crew is in the right location and measuring the right tree at all times within the trial.
- If possible, data from at least one previous test assessment should be available to each team during the measurements. This can help with resolving problems and can speed up the measurements.
- Each crew team member needs to fully understand his or her responsibility during measurements. The trees should be assessed and data entered in the same order to minimize errors (e.g. tree status, height, diameter, condition).
- A genetic test measurement report needs to be submitted to ATISC together with checked raw data and quality control summary statistics.

3. HEIGHT AND DIAMETER MEASUREMENTS

ATISC standard operating procedures (SOP) for height and diameter measurements are included in the Appendix 2 and 3, respectively. It is strongly recommended to review both SOP's.

- Tree height is measured as a vertical distance between the ground immediately next to the stem base approximating the germination point and the highest point on the main stem (terminal bud or needles). In case of multiple leaders, the height of the tallest leader should be measured. See Figures 1, 2 and 3.
- Trees leaning up to 15 degrees off of the vertical axis should be measured (cosine of 15 degrees angle is 0.97 resulting in a measurement within the allowed error). The height of these trees should be measured vertically as explained above. **Height of trees leaning more than 15 degrees should not be measured and these trees should get an "L" condition code.** See Figures 4 and 6. Take the measurement if in doubt whether the tree leans more than 15 degrees.
- Recommended maximum height of trees to be measured by a height pole is 6 m. The Vertex III (or Vertex IV) hypsometer is recommended for tree height measurements over 6 m.
- Tree diameter at breast height (DBH) should be an outside bark measurement at a tree height of 1.3 m (Figure 7). The height of the DBH measurement should be marked on the stem with a single bar using a lumber crayon.
- On sloping ground, DBH is to be measured at 1.3 m from mid slope (Figure 7).
- On trees which are leaning DBH is to be taken on right angle to the center line of the tree (Figure 8).
- If a whorl, deformity, distortion or branches occur at DBH, the diameter must be measured immediately above the irregular section (Figures 9 and 14). The distance above 1.3 m does not need to be recorded but the location of the DBH measurement needs to be marked with a single bar as explained above.
- On trees where forking is present below DBH, measurement is taken on the tallest stem (Figure 10).
- On trees where forking starts at DBH, measure immediately below the origin of the fork (Figure 11). The distance below 1.3 m does not need to be recorded but the location of the DBH measurement needs to be marked with a single bar as explained above.

4. TREE STATUS AND CONDITION

In addition to growth measurements, tree status and condition need to be assessed. Below are the tree status and condition codes used by ATISC. As different codes can be used by different organizations, the codes must be defined for each data set.

ATISC tree status codes:

1 = Tree is living and generally healthy

2 = Tree is dying or seriously unhealthy

3 = Tree is dead. If cause of death is known, identify in comments.

4 = Tree is not found

5 = Tree is living and noticeably unhealthy

6 = Tree is dead due to animal or mechanical damage

7 = Tree is unplanted or non-experimental (ingress) tree

ATISC tree condition codes:

A = **Animal** or **mechanical** damage that **significantly** affects tree growth*

B = Broken top

C = Chlorosis (>50% of crown is affected)

D = Dieback of terminal shoot due to agents **other than terminal weevil***

F = Flushed shoots are browned and drooping (>10% of newly flushed shoots are affected)

KL = Forking or multiple leaders in lower portion of stem (below stem height of 1.3 m)

KU = Forking or multiple leaders in upper portion of stem (present at least 2 growing seasons before assessment)

L = Leaning tree (>15^{o} from vertical)

P = Pest, **insect** or **disease other than western gall rust or terminal weevil***

RSn = Gall rust on stem, n = record exact or approximate number of galls (if more than 10 galls are present, roughly estimate the number of galls in increments of 10)

RBn = Gall rust on branches, n = record exact or approximate number of galls (if more than 10 galls are present, roughly estimate the number of galls in increments of 10)

QL = Crooked stem in lower portion (basal sweep)

QU = Crooked stem in upper portion

TN = Dieback of new terminal shoot due to weevil attack (i.e. top of the leader is dead)

TO = Dieback of old terminal shoot due to weevil attack (i.e. a new leader formed above the dead one) (see Figure 16 on page 22 for examples of TN and TO)

W = Winter desiccation (>10% of foliage is browned due to winter desiccation)

X = Tree is growing on a spot that is noticeably poor microsite (e.g., planting spot frequently flooded, low planting spot, tree next to stump or stony patch, frost heaving, etc.)

Additional tree condition codes specific to deciduous species:

H = Hypoxylon canker (aspen)
S = Septoria canker (poplar)
V= Venturia, tip and/or tip plus branches

*If known cause, identify it the comments. A good example of animal damage would be a porcupine feeding on the bark around ¾ the bole of the tree. For condition with frequent occurrence identify the cause in the measurement report rather than in the comments. If the cause of a condition is unknown but the condition is frequent or unusual (e.g. suspect a new disease), take photographs and include them in the measurement report. If possible, collect samples to help identify the cause.

Conditions listed above must be recorded for each tree during measurements. Additional codes may need to be used for unlisted and frequent conditions. Infrequent conditions should be identified in comments.

Frequent conditions can also be recorded in a data column instead of a condition column. In tests with frequent terminal weevil attack create a weevil data column and record TN as 1, TO as 2 and unaffected trees as blanks. In tests with frequent western gall rust infections create separate columns for RS and RB and record the exact or approximated number of galls (leave blanks for unaffected trees).

It is recognized that in addition to routine measurements, additional specific assessments may be needed as often identified during routine measurements. Good examples are foliar disease diagnoses and severity assessments which may need to be done in a different time than routine measurements and are often performed by specifically trained personnel.

5. QUALITY CONTROL FOR FIELD TRIAL MEASUREMENTS

Alberta FGRMS standards (2016) 30.10.3 and 30.10.5 identify the needed precision of height and diameter measurements, respectively. Up to 10% of audited trees may deviate more than 10% from the values measured during the audit. When, for example,

50 QC trees are measured, height or DBH measurements of a maximum of 5 trees (i.e. 10% of measured trees) can deviate more than 10% from the check value.

Selection of quality control trees can be done randomly or systematically within the trial (see below for sample size). All replications should be sampled. Systematic selection may be preferred as it should minimize errors associated with measuring wrong trees and would likely result in faster QC data collection. For example, quality control trees can be systematically selected along tiers perpendicular to rows and distributed uniformly across replications until the required numbers of trees have been re-measured. In any case, it is best to identify QC rows using establishment maps prior to re-measurement so the location of each row can be entered on the quality control sheets. Once at the QC row the first tree in the row can be used. If this tree is dead or not representative of trees in the test (for example extremely small), another tree in the row can be used and the tree number recorded on the QC form. The QC measurements can be done before or immediately after the whole test measurements.

QC sample size for a single test site depends on the total number of trees planted in the site:

- Site with < 1000 trees: at least 5% of the trees must be measured and a minimum sample size must be 30 trees.

- Site with 1000 to < 3000 trees: at least 4% of the trees must be measured and a minimum sample size must be 50 trees.

- Site with ≥ 3000 trees: at least 3% of the trees must be measured and a minimum sample size must be 120 trees.

APPENDIX 1. RECOMMENDED FIELD EQUIPMENT PER CREW

- 10-50m metric measuring tape (metal preferred) for hypsometer calibration.
- Two metal diameter tapes (metric) with millimetre graduations.
- Two telescoping metric measuring poles if trees are less than 6 m in height.
- Tree height measuring device – hypsometer – (e.g. Vertex) >6 m trees.
- Four AA alkaline batteries for Vertex and Transponder.
- Vertex User Guide.
- GPS receiver to locate site – optional.
- Coloured flagging.
- Handheld data collection computer or waterproof tally sheets.
- Laptop to back up daily data from handheld devices.
- Charging cradle, backup batteries and power adapter for handheld computer.
- Measurement software operating instructions.
- Waterproof bags to protect measurement instruments and tally sheets.
- Clip board.
- Establishment report and map of experimental trial.
- Site/trial assessment form for recording work needed in the site (e.g. damaged fence, brush).
- Quality Control assessment sheets.
- Tree Assessment Code sheets.
- Radio/cell phone.
- Pencils and pens.
- Lumber crayons and lumber crayons holders.
- Waterproof boots and outerwear to match weather conditions.
- Gate key or a combination to gain access to site.
- Rubbing alcohol to clean diameter tapes and telescoping measuring pole.
- 1.3 metre stick for locating DBH on tree to attach Vertex Transponder for consistent location of 1.3 metres on the tree bole when conducting measurements with this electronic hypsometer.
- A small saw or an axe for cutting ingress trees.
- Digital camera.

  At the beginning of each replication take 3 pictures. Offset yourself at 2.5 meters from the row and go back at 7.5 meters from the first tree. Take one photo down the row at eye level. The second photo is taken halfway up the trees in the replication and the third photo is taken of the tree tops of the replication.

APPENDIX 2. HEIGHT MEASUREMENTS ATISC SOP

Vertex height measurements

The Vertex III (or Vertex IV) hypsometer is used by ATISC for tree height measurements over 6 m in height. This device is economical, light, portable, accurate, useable in closed stands, not very sensitive to user fatigue and operator variation and has a low level of inherent error (< 1% error). It can be used in temperature range of -15 to 45 ^{o}C.

2.1 Vertex Calibration and Associated Measurement Error

- **IMPORTANT –** the Vertex uses ultra sonic signals to determine distances. Humidity, air pressure, surrounding noise and, most of all, temperature can affect measurements. Although there is an automatic built-in temperature sensor that compensates for temperature changes, this is insufficient to prevent the Vertex from drifting out of calibration. As a result, in order to minimize the introduction of height measurement error associated with Vertex calibration drift, the Vertex must be calibrated in the morning when it is cool and once again if change in temperature is greater than 10^{o}C. To prevent errors due to Vertex calibration in quality control measurements the Vertex should also be calibrated regularly during quality control checks. Field testing of the Vertex indicates that failure to calibrate the Vertex regularly (at least twice a day) can introduce a measurement error in the range of 1% to 5% in height measurement depending on environmental conditions and their change over time.

- When calibrating, it is important that the Vertex has been given enough time to stabilize to the ambient temperature. If, for example, the Vertex is carried in an inner pocket, it can take up to 10 minutes before it has adjusted to current outdoor temperatures.

- **CALIBRATING** - measure a distance of 10.0 m between the transponder and the Vertex front with a tape. Start the Transponder and Vertex, step in the menu to **CALIBRATE** and press and hold **ON**. The Vertex will calibrate to 10.0 m and automatically turn off when ready.

2.2 Additional Sources of Height Measurement Error when Measuring with a Vertex Hypsometer

- Placement of the Vertex transponder off of DBH (1.3m) can result in additional height measurement error beyond that caused by inherent error in the Vertex and error due to poor calibration. Field testing indicates that being off 10 cm in DBH height (1.3 m) can introduce and error of 1.1% and 20 cm off of DBH can add up to a 2.2% error.

- Another source of error which is related tree height and horizontal distance from the point of tree height measurement. When taking height measurements the operator should always be located at a distance greater than or equal to the height of the tree (see below).

- Under all circumstances the surveyor operating the Vertex must see the top of the tree that is being measured as this is critical to correctly determining the angle used by the Vertex to apply the trigonometric function used to calculate height. If confirmation of the proper tree top is required, the person operating the transponder or measuring DBH can shake the tree so the top of the appropriate tree can be correctly determined. See Figure 1 for an example of clear viewing window.

2.3 Procedures for Height Measurements Using Vertex

1. Press the ON button to start Vertex.
2. Turn Vertex ON and arrow to SETUP, press ON, change setting to Metric, change to Type 2 (or “Deg” on different versions of the Vertex), P.offset should be 0.3 m, T.Height set at 1.3 m(DBH), M.distance set to 0.0, BAF is NA.
3. Press both arrow keys simultaneously to shut Vertex OFF.
4. To turn the Transponder ON, point the Vertex loudspeaker directly towards the transponder and press the left arrow key until two short beeps are heard from the transponder (Vertex must be OFF).
5. Repeat above step; wait for four short signals to turn the transponder unit OFF.
6. **When taking height measurements the operator should be located at a distance greater than or equal to the height of the tree** (i.e. if measuring a 10 m tree, the operator should be at least 10 m away from the tree). The operator can use the 2.5m spacing of the planted trees as a guideline to the correct distance away from the tree – 4 trees away at 2.5m is equal to 10 m. This distance can also be confirmed in the Vertex window after the bottom reading is taken.

7. Turn Vertex ON (Height should be displayed) and aim towards the transponder held at DBH (1.3 m). Press ON and hold until the cross hair sight is not visible. Now release the ON button. (The Vertex now has the distance, the angle and from this calculates the horizontal/slope distance to the transponder).
8. Aim the Vertex's red cross hairs (cross hairs should be blinking) at the vertical point on the tree to be measured (usually the tree top measurement point). Push ON until the hair cross disappears which indicates the vertical angle for the top of the tree has now been locked in and you can release the ON button and the red cross-hair comes back flashing again. To reduce the chance of measuring a lower height due to the lowering movement of the Vertex prior to the machine finishing its height calculation, you should wait until the cross hairs return flashing red before lowering the machine and recording the first height taken. (Six heights can be taken per tree using the initial bottom of the tree reading but full tree height measurement only needs 1).
9. Turn Vertex OFF and then turn it ON ready for next tree. Important to turn Vertex completely off after each tree so that the correct HD/SD and angle for each individual tree is only used for that tree only and not other trees.
10. For forked trees, the height is taken on the stem that is tallest and must be taken from a location perpendicular to the fork so that the surveyor gets a good view of the tallest tree top (Figures 2 and 3).
11. For leaning trees that are between 5 to 15 degrees off of the vertical axis the measurement procedure should remain the same in order to attain a vertical measurement from the ground rather than a stem length measurement (Figure 4). If lean is greater than 15 (16 to 90) degrees off of the vertical axis then height should not be taken and the tree should be given an "L" code.

2.4 Vertex Notes

- The red cross-hair light can be adjusted using the left arrow key when aiming.
- Horizontal distance can be taken by turning the transponder ON, aiming the Vertex at transponder (DBH) and pressing the DME (forward button).
- Check the Vertex twice a day and recalibrate (after it has reached ambient temperature); record variables and other pertinent information on the Vertex calibration check list for that day.
- Do not touch the temperature sensor at the front of the instrument.
- 1.3 m is already added to Heights if T. Height is set to 1.3 m in SETUP.
- The transponder can be "Hooked" onto the tree with the hook provided on the back of transponder or held parallel to the tree bole to get the correct horizontal

distance for calculating tree height (use 1.3 m stick for correct DBH location) on straight trees.

- On leaning trees DBH measurement point is not where the transponder should be held. On leaning trees the transponder should be held at 1.3m in line with the point at which the tree height is taken (Figure 4).
- When collecting height measurements using Vertex, the transponder may not be clearly visible to the Vertex operator if understory is thick or stem density is high. In order to indicate the location of the transponder to the Vertex operator a pink DBH stick may be held out perpendicular to the vertex location to indicate transponder location (Figure 5).

2.5 Troubleshooting the Vertex

- When computing Heights, if the ON button is pressed once and released you are in manual distance mode. If this occurs, turn the Vertex OFF and then ON and follow #7 and #8 above.
- Refer to User Guide for Vertex and Transponder for additional information.

<u>Pole height measurements</u>

- Recommended maximum height of trees to be measured by pole is 6.0 m.
- Spotter should stand at 90 degrees from the plane of the pole handler and tree.
- For leaning trees that are between 5 to 15 degrees off of the vertical axis the height pole should be held vertically (perpendicular to the ground) and the spotter should look along the plain from the top measurement point of the tree to the top of the height pole to obtain a height for the leaning tree (this provides a vertical height from ground rather than a stem length measurement). If lean is greater than 15 (16 to 90) degrees off of the vertical axis then height should not be taken and the tree should be given an “L” code.
- Pole handlers are to maintain the pole as parallel and as close to the tree as possible. (May want to feed pole up through branches close to bole of tree and attach a bright color of flagging to the hook on top of pole for sighting purposes).
- Pole handler to insure that the base of the pole is at the same level as tree root collar. This is important on uneven ground.
- See Figure 6 for most common sources of height errors using a pole for measurement.
- When using telescopic poles, make sure that appropriate sections are extended for each measurement.

Figure 1. Viewing window for tree height measurement with the Vertex.

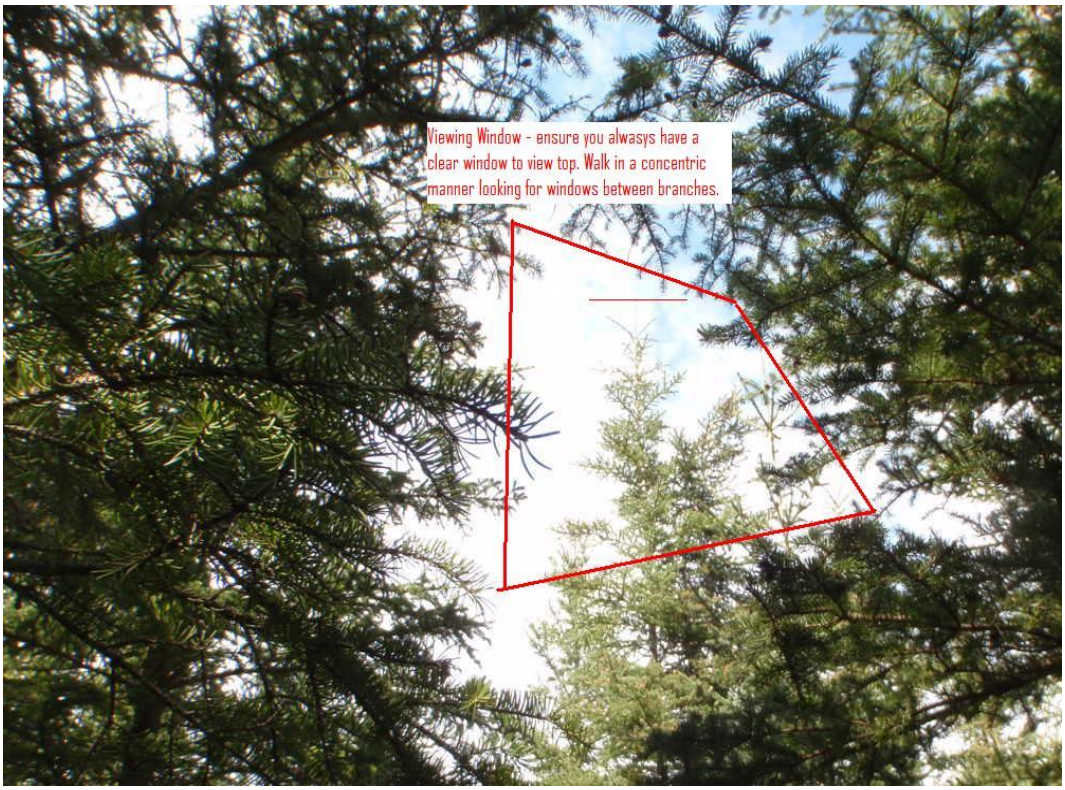


Figure 2. Height measured on tallest stem.

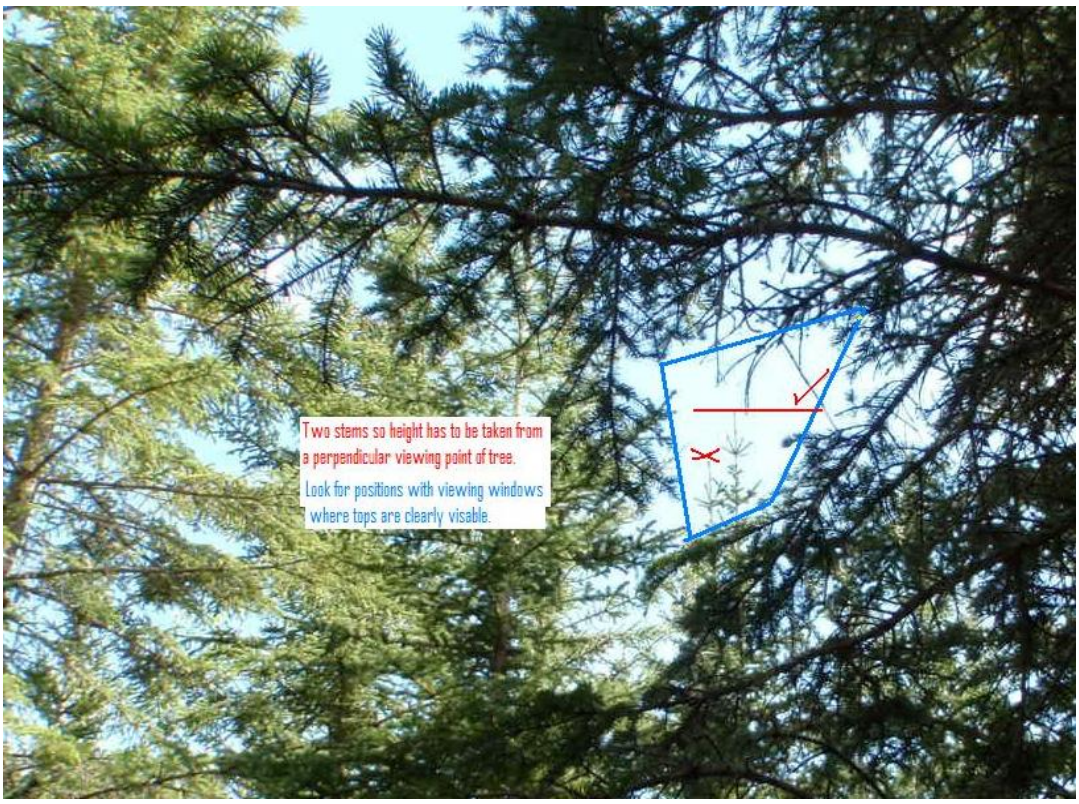
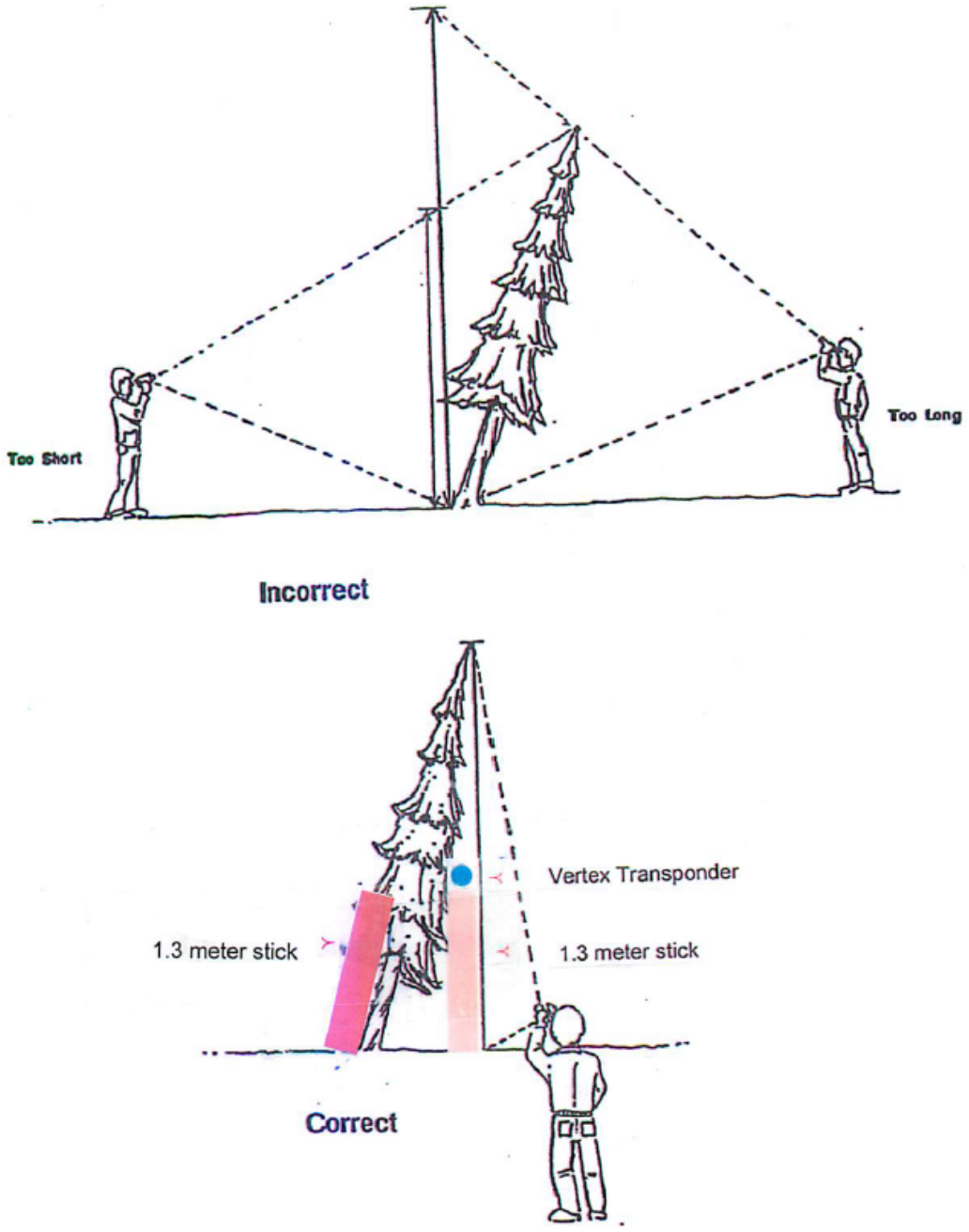


Figure 3. Perpendicular view for height measurements.

Figure 4. Height and DBH measurements on leaning trees.



HEIGHT MEASUREMENT OF LEANING TREES

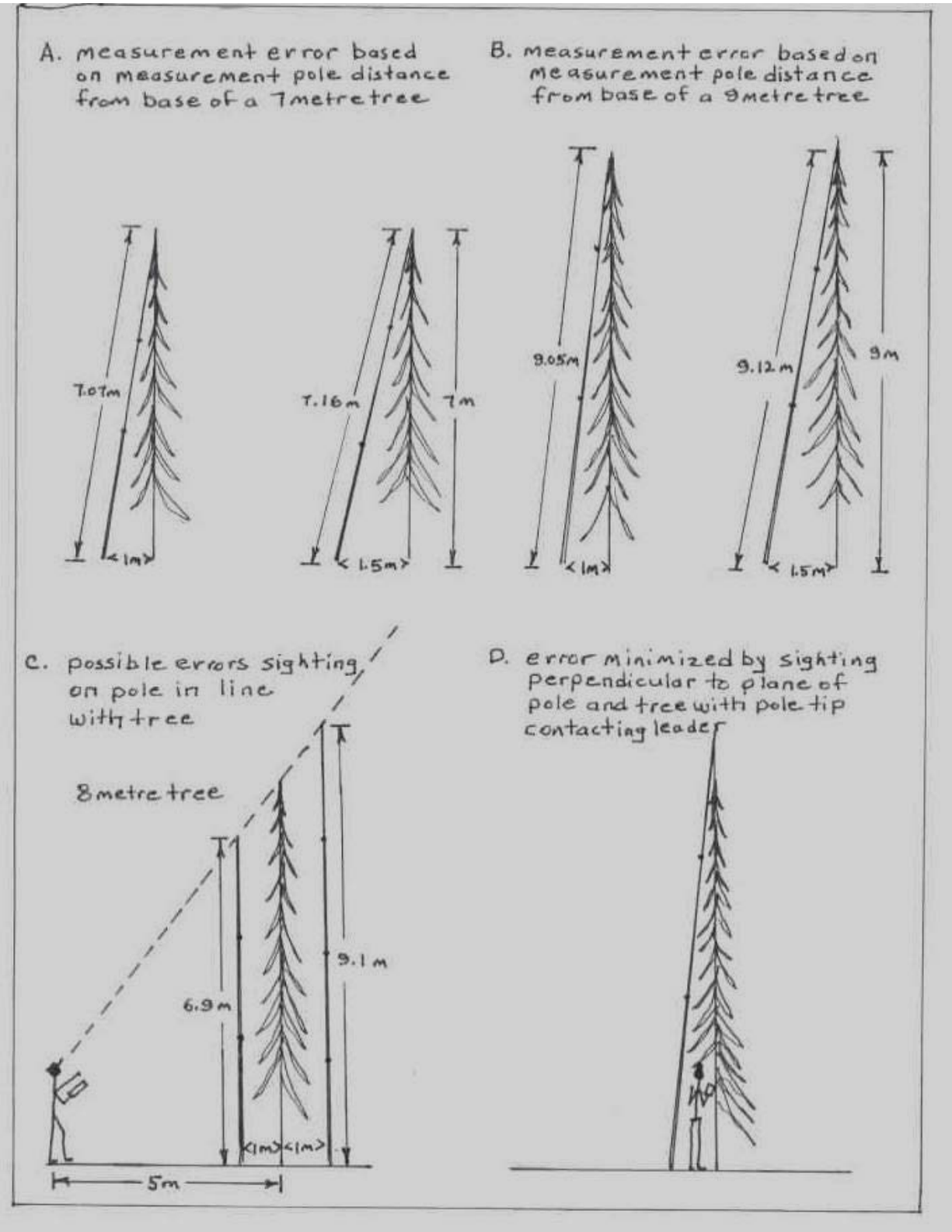
(Placement of stick has to be on level ground same level as tree point of germination)

DBH MEASURMENT OF LEANING TREES

(DBH should be taken along the stem, at the same angle as stem, at point indicated by 1.3 m stick)

Figure 5. Vertex transponder visibility at DBH.

Figure 6. Sources of height measurement errors using height pole.



APPENDIX 3. DIAMETER MEASUREMENTS ATISC SOP

- Diameters at breast height are to be taken over the bark at 1.3 m above the germination point of tree (Figure 7).
- To reduce DBH location errors when conducting QC, all DBH's location should be marked with a red/blue/yellow lumber crayon on the side of the tree facing the beginning of the row when doing the initial measurement. A single bar the width of a diameter tape (Figure 14) should indicate DBH location of the measurement. If DBH is not measured at 1.3 m (due to e.g. deformity at 1.3 m), two bars should indicate the 1.3 m location (Figure 14) where the Vertex transponder has to be positioned to get the correct tree height (+/- 5%).
- Measurement personnel assessing DBH and working with the hypsometer transponder where DBH **is not** marked on the tree should use a 1.3 m stick for locating DBH/transponder location. The stick must he held right against the bole of the tree for exact location of DBH and measurement of horizontal distance by the transponder.
- Metal diameter tapes are required because they deform less (by hauling or by temperature) than those made of synthetic material.
- Insure that the correct side of the DBH tape is read.
- Diameter to be measured to the closest tenth of a centimetre and recorded in cm.
- Diameter tape must be correctly positioned at the point of measurement (1.3 m), ensuring that it is kept in a perpendicular plane to the axis of the stem, that it is set firmly around the tree trunk with no obstructions present underneath.
- On sloping ground, DBH is to be measured from point of germination or mid slope (Figure 7).
- On trees which are leaning; DBH is to be taken on right angle to the center line of the tree (Figure 4 and 8).
- If a tree whorl, deformity, distortion, or branches are present at DBH (within 5 cm), the cruiser must measure the diameter immediately above the irregular section (Figures 9 and 14). This is a source of major DBH measurement error and must be practiced consistently across every trial measurement. If the height of DBH measurement is not marked on the tree, note in comments section how far up in centimeters from original DBH the new DBH location is.
- On trees where forking is present below DBH, measurement is taken on the tallest stem (Figures 10, 12, 13 and 14).
- On trees where forking starts at DBH, measure immediately below the origin of the fork (Figure 11).

- On fallen trees, DBH is to be taken at 1.3 m along the horizontal trunk of the tree from the point of germination (Figure 15).
- Rubbing alcohol should be used to clean the diameter tape of resin build-up.

Figure 7. DBH measurement from point of germination.

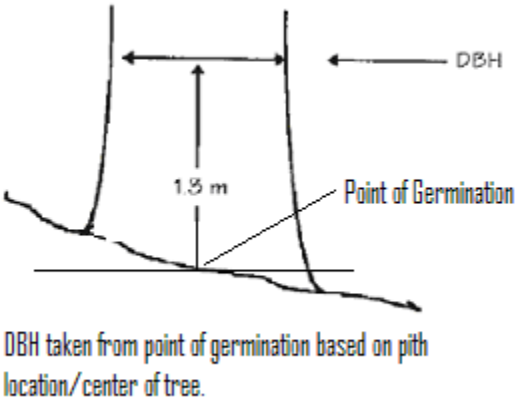


Figure 8. DBH measurement on leaning trees; measure at right angles to centre line of tree.

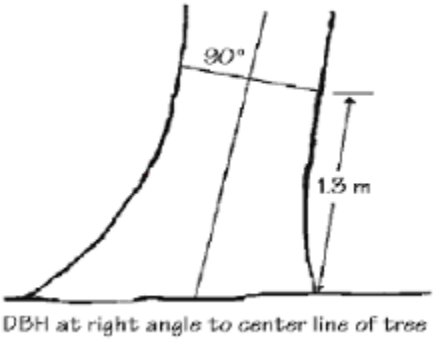


Figure 9. Deformity at DBH; measure immediately above.

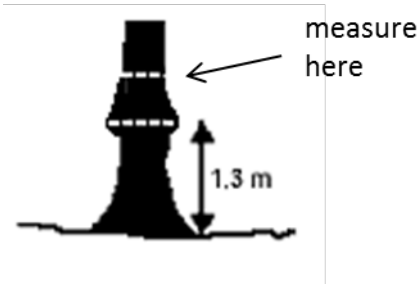


Figure 10. Forking below DBH; measure tallest stem.

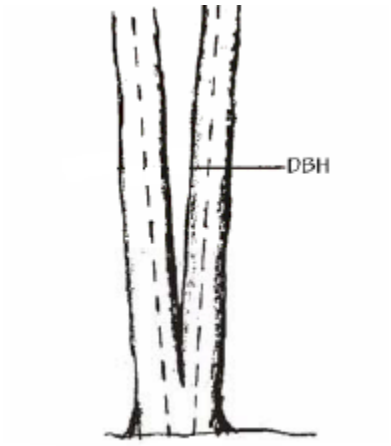


Figure 11. Forking at DBH; measure directly below DBH.

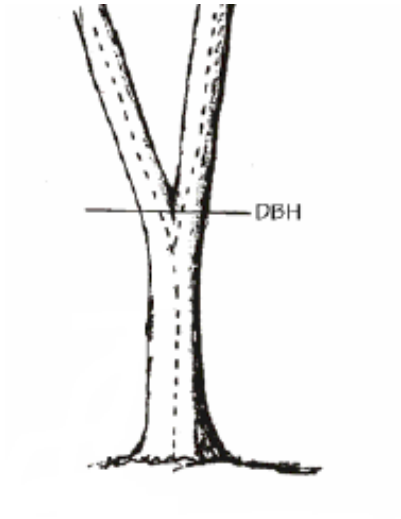


Figure 12. Multiple stems below DBH.

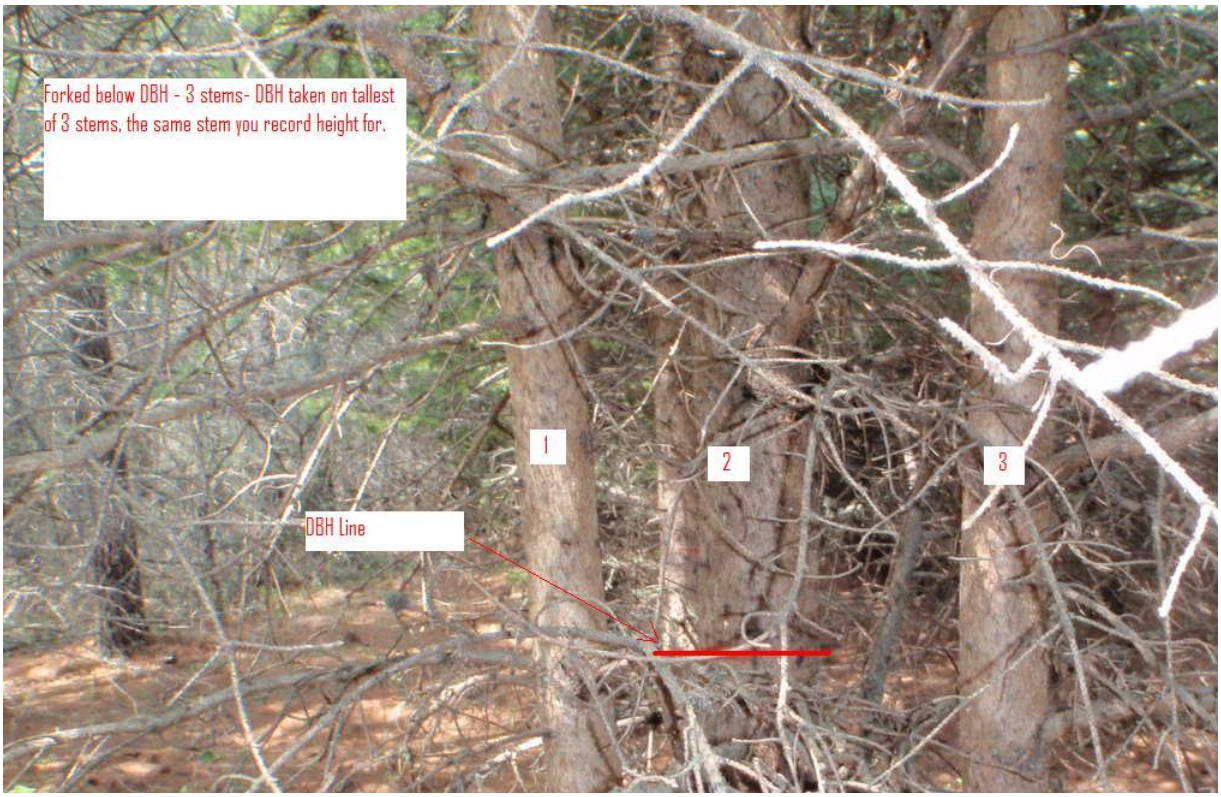


Figure 13. DBH measured on tallest stem.

Figure 14. DBH measured on a tree with unusual forking.

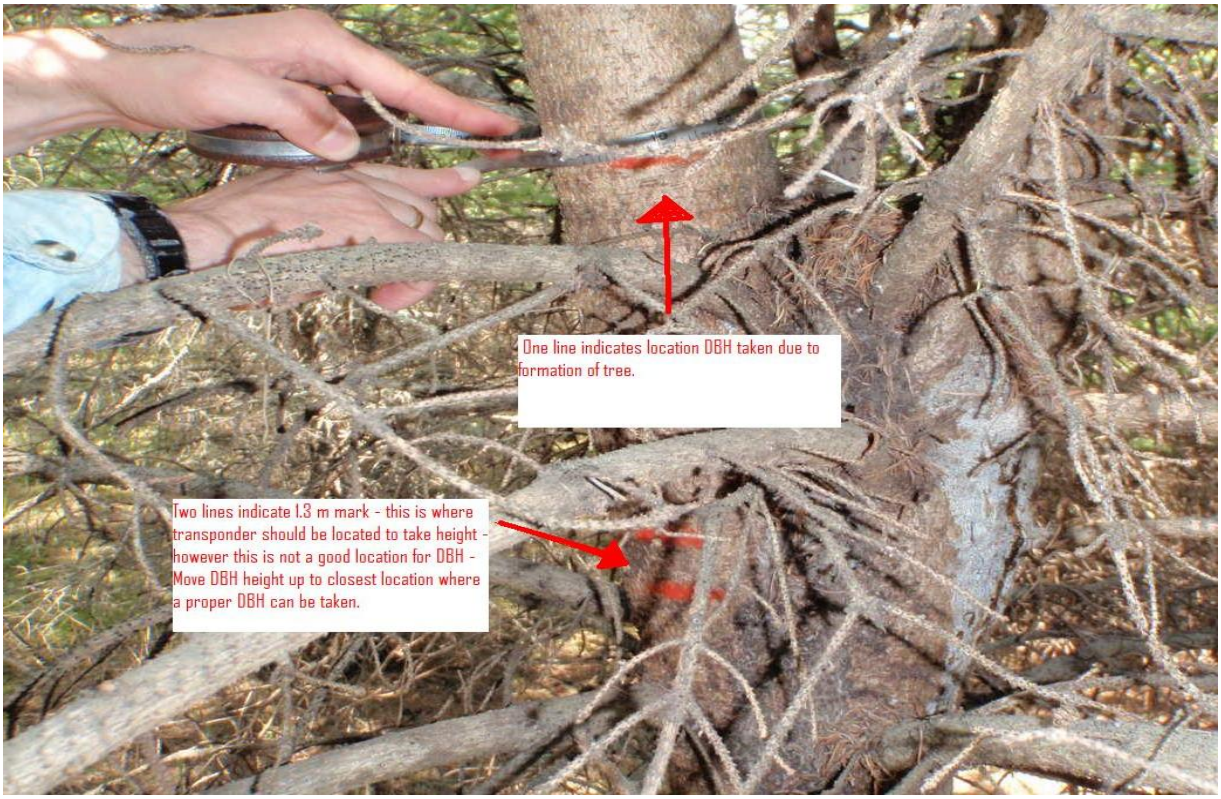


Figure 15. DBH measured on fallen living trees.

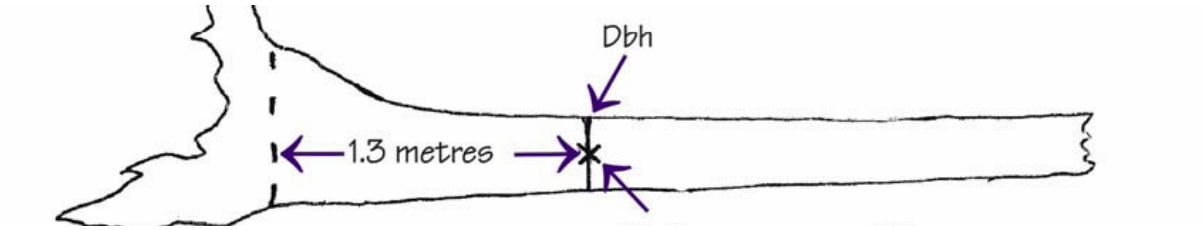


Figure 16. Examples of terminal weevil damage condition codes TN and TO. (TN - dieback of new terminal shoot, TO - dieback of old terminal shoot). A = TN, B = TO recent, C = TO older (note that the dead old terminal shoot may not be easily visible, look for “crow’s nest”), D = TN and TO on the same tree.