Measure up!

A Skogforsk Guide to Harvester Measurement

Contents

This guide was written by
Maria Nordström, Skogforsk and
Jonas Hemmingsson, VMF Syd.

Editor: Carl Henrik Palmér,
Areca Information AB
Layout: Inger Petré, Skogforsk
Cover photo: Jonas Hemmingsson, VMF Syd
Other photos: Skogforsk unless stated otherwise
Illustrations: Per Thorneus, Pictoform
Publisher: Skogforsk

ISBN: 978-91-88277-04-6
Printer: Gävle Offset

Foreword

Every day, timber, pulpwood and energy wood representing large economic values are harvested in forests. In order to maximise timber value, and to minimise waste when making specific products, the harvester must be able to measure the length and diameter of the stem with great accuracy. This requires smooth-running technology, correct settings and an efficient working method.

As operator, you play an important role in ensuring that the harvester is measuring accurately. It is your manual control measurement of stems that is the result against which the machine is adjusted. Correct use of the calliper and meticulous measurement of length during checks and calibration are vital if the harvester is to measure really well.

Our aim with this guide is to provide an overview of how the measurement system on the harvester works, and to show how you can work systematically with checks and adjustment of the measurement system. We hope this will help you in your work.

Good luck!

Harvester measurement of length and diameter

Doing things correctly from the start generates value throughout the production chain.

During processing, the harvester measures the diameter of the stem and how far the stem has been fed through the head. The stem dimensions are used by the on-board computer to calculate what logs are to be made from each stem.

Modern harvesters can measure length and diameter with great precision (Figure 1), but this requires continual monitoring of the harvester's measurement results.

Efficient measurement means that the measurement process is running smoothly. The stem can be fed through the head as intended, and there is less need for the head to reverse and restart further back along the stem.

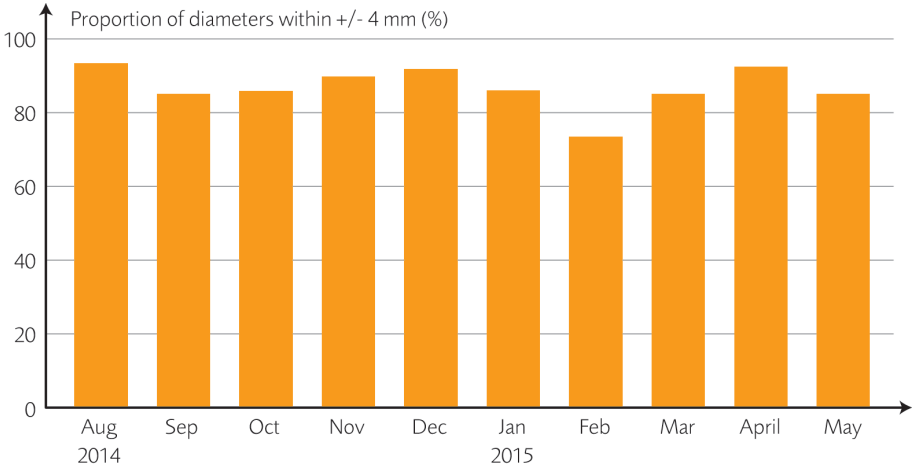


Figure 1. Example of a harvester in final felling that consistently measures stem diameter with great precision. This harvester is quality assured, so the machine team is given continual follow-up and feedback by an independent harvester auditor.

How the harvester measurement system works

The stem length is measured with a measuring wheel attached to the body of the harvester head.

The sensors for diameter measurement are placed either in the upper delimbing knives or in the feed rollers. Modern harvester heads usually record at least three points around the stem at each measurement point. The on-board computer then calculates the diameter of the stem based on these measurement points. For the butt part of the stem, where the head has not measured any diameter, the diameter is calculated using a function for the tapering of the stem.

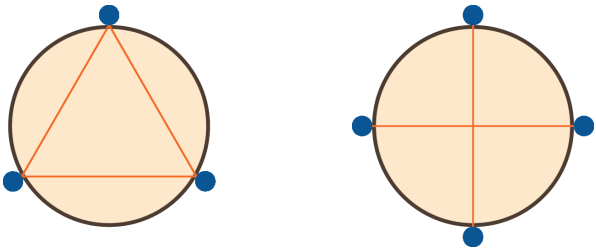


Figure 2. Modern harvester heads calculate the stem diameter at every measurement point as the diameter of a circle. The diameter is determined either through triangulation based on three measurement points (three-point measurement, left) or as the average of the diameter in two perpendicular measurement orientations (four-point measurement, right).

If the harvester records an increasing diameter for the stem when measuring from butt to top, such as over a branch stub, the computer will filter the measurements and create a 'flat area' until the diameter measurement returns to normal.

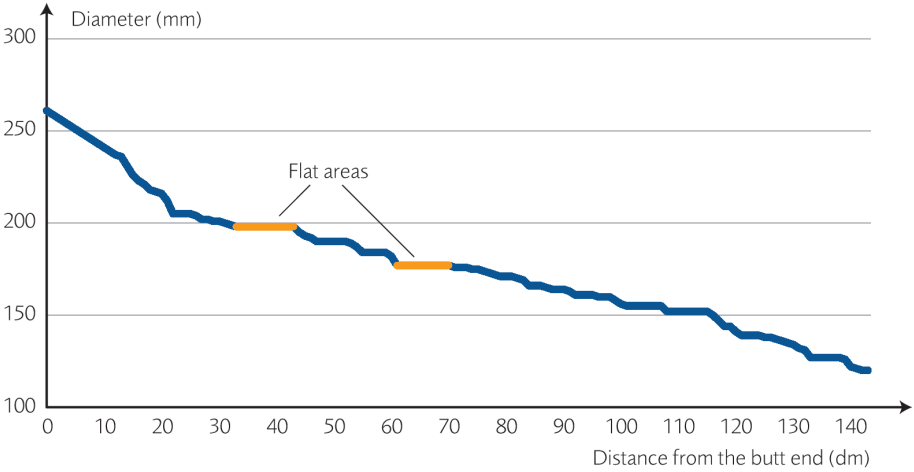


Figure 3. The measuring device has recorded a stem profile (blue) where the diameter, at several points, increases towards the top. The on-board computer filters out these diameter increases and, instead, sets the diameter to unchanged until it has returned to the original value. This creates 'flat areas' in the stem profile.

What affects harvester measurement?

Modern harvesters have the technical capability to measure stem dimensions with high precision but, in practice, the harvester's measurement results are affected by a number of other factors:

- **Machine selection** – A fundamental condition is that the harvester size is appropriate for the stand. The harvester must be strong enough to hold the tree during processing.
- **Technical maintenance** – Mechanical faults and wear in the diameter sensors, delimbing knives, feed rollers and measuring wheel reduce the accuracy of measurement.
- **Machine settings** – Pressure settings for the delimbing knives, feed rollers and measuring wheel, feed speed, etc. are important for the harvester's capability to measure accurately.
- **Calibration** – The measurement system must be adjusted so that no systematic over- or underestimates of length and diameter occur.
- **Operating style** – The measurement results are affected by how well the operator follows the stem with the crane during feeding and the extent to which heavy logs are supported on the ground rather than hanging freely when cutting.
- **External factors** – Stand properties (tree ovality, number of branches, thickness, bark etc.), temperature, the period of rising sap, etc. can quickly change the conditions for measurement. Particularly critical are periods when the bark is changing, i.e. during the period of rising sap during the spring, when the trees become dormant during the autumn, when the bark freezes during the first really cold spell in the winter, and at the end of the winter/start of spring, when the bark is frozen during the night and thaws during the day. During cold periods, heads where the measuring wheel is placed inside a hydraulic cylinder may experience problems when measuring length – as the oil cools down, the measuring wheel can lose pressure and then cannot follow the surface of the stem.

Machine settings

A machine with the correct settings not only improves measurement – it is also smoother in operation and there is less need for the head to reverse and restart.

The pressure settings for the upper and lower delimbing knives and feed rollers are examples of machine settings that directly affect measurement. This applies to both the fixed pressure and the settings for pulsating the pressure. Pulsation helps to maintain the pressure in the hydraulic system and to straighten the stem in the head. Pressure can be reduced to facilitate movement when the feed is starting, or increased to prevent the feed rollers from slipping at the start. For measurement of length, the pressure on the measuring wheel is important. The range of settings may differ somewhat between harvesters.

The pressure from delimbing knives and feed rollers must be sufficient to hold the stem firmly without retarding the feed. The pressure is set specifically for every diameter class, and it is important that settings are correct for all diameter classes.

Foto: Rottne Industri AB

How well is the harvester measuring?

How well the harvester is measuring can be described with performance indicators (key figures) calculated from the manual control measurements. The indicators can be used to describe the differences between how the machine (M1), operator (M2) and auditor (M3) have measured the length and diameter of one or more stems.

- **Proportion of measurements within +/- X mm/cm** – This is the proportion of measurements within a certain interval from the machine operator's or auditor's control measurement. For diameter measurement, this is usually the proportion of measurements within ± 4 mm from the control measurement, and for length measurement the proportion of measurements within ± 2 cm. These performance indicators, also called the accuracy percentage, capture both the dispersion (spread) of measurements and systematic errors.
- **Standard deviation** – This describes the dispersion in the harvester's measurements. The lower the standard deviation, the more precise and consistent the measurements. Standard deviation is expressed in mm for diameter measurement and in cm for length measurement. A high standard deviation indicates that the measurement procedure is not working as it should, probably because of a mechanical fault or incorrect machine settings.
- **Systematic deviation** – If the harvester is consistently measuring length and diameter as too long or too short, the measurement has a systematic error, expressed in mm for diameter measurement and cm for length measurement. A systematic error can often be corrected by calibrating the measurement system, but you must first ensure that the error is not caused by a mechanical fault, for example a component may have been moved out of position.

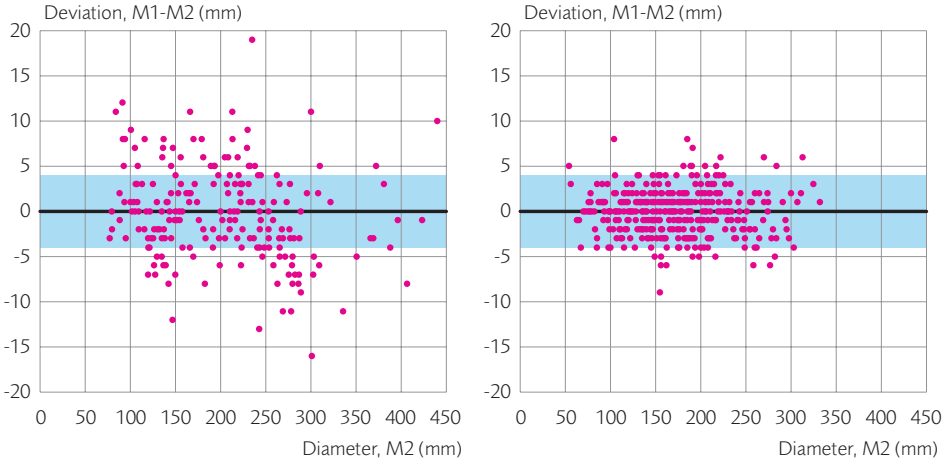


Figure 4. The harvester to the left measures 64% of the diameter measurements within ±4 mm, with a standard deviation of 5.1 mm. The harvester to the right shows very accurate measurement, with 93% of the diameter measurements within ±4 mm, with a standard deviation of 2.5 mm. The systematic error is very low for both harvesters, suggesting that both are well-calibrated. However, the operator of the left harvester could improve measurement accuracy by checking for mechanical faults in the measurement system and by checking the machine settings.

Manual control measurement

By continually monitoring the harvester's measurement, you can detect and correct measurement errors before large log volumes have passed the harvester head.

Continual monitoring usually involves manual control measurement of, on average, one stem per shift. Manual control measurement is also performed to collect data for calibration. The control measurement is performed according to the same procedure, irrespective of whether the measurement is for a check or calibration[1].

If you suspect that measurement is deviating from the norm, you may need to perform control measurements of extra stems to ensure that the error was not just temporary, and to decide on how the measurement will be corrected.

1 Except heads with two-point measurement, where data for calibration is collected according to the manufacturer's instructions.

Procedure for quality assurance

The standard system in the sector for quality assurance of harvester measurement is based on internal audits through manual control measurement of a randomly selected number of control stems. Every quality-assured harvester also has an external auditor who provides regular feedback on how the harvester is measuring and who visits the teams in the field. Random selection of stems helps give you a picture of how the harvester is measuring on all types of stem. If a randomly selected stem should prove to be unsuitable as a control stem, for example because the harvester measurement is clearly incorrect, it can be rejected in the on-board computer and a new stem randomly selected later. The signal that a tree has been randomly selected is given when you have locked the cut for the butt log.

Preparations for control measurement

Arrange the control logs on a support so that you can access the entire length with the calliper and measuring tape, and to keep the logs separate from other timber.

Photo: Jonas Hemmingsson, VMF Syd

The control logs should be placed on a support for easy access during manual measurement.

Transfer the machine measurements from the on-board computer to the calliper. Measure log-by-log from the butt log upwards towards the top of the tree.

Control measurement of log length

Control measurement starts by measuring the length of the log. Place the end of the measuring tape at the butt end of the log. Make sure the attachment hook is pressed firmly into the wood, perpendicular to the log, otherwise the length measurement will be incorrect. Draw the measuring tape along the log, read off the length, rounded to the nearest cm and enter the data in the calliper[2]. When using a digital measuring tape, the calliper rounds the measurement according to the same principle. You then record the length using the marker at the same height as the log end.

Photos: Johan Heurgren Film AB

Control measurement of log length. Round to whole cm according to Swedish Standard (left). The attachment hook is pressed completely into the wood (right) to ensure that the length is measured correctly.

[2]When the only decimal is 5, the figure is rounded to the nearest even whole number.

Control measurement of stem diameter

The first diameter measurement is the top diameter of the log. Diameter measurements are then taken along the log, from the top down to the butt end. On butt logs, the final diameter measurement is taken at breast height up from the butt.

Because logs are rarely completely round, you should take two diameter measurements perpendicular to each other at every measurement point. Where logs are extremely oval, the two measurements should be taken where the log's diameter is greatest and smallest respectively.

If the measurement point is precisely on a branch stub or a bulge, you should move the calliper along the stem towards the butt end and instead measure the diameter at the smallest diameter below the bulge. NB. This also applies to the top diameter

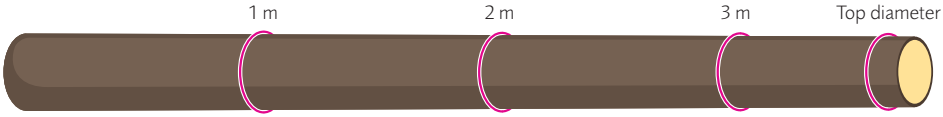
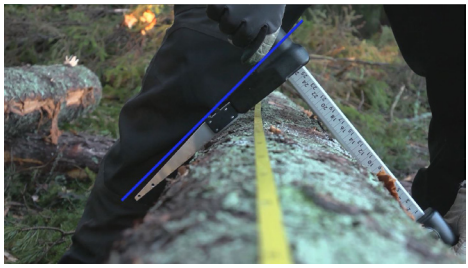


Figure 5. In Sweden the first diameter measurement is cross-callipered 10 cm down from the top end of the log. The diameter is then measured every whole metre along the log down to the butt end. If the top measurement is ocated on a bulge, the measurement should instead be taken at the smallest diameter below the bulge towards the butt. This also applies to the top diameter.

All control measurement is carried out on bark. If the bark is missing, you should as far as possible measure in directions where there is still bark. In other cases, you should add the thickness of bark of the same type as that which has been worn away.

When the control measurement is complete, place the calliper back in the holder. In newer harvesters, the files containing control measurements will then be automatically transferred to the on-board computer.



Photos: Johan Heurgren Film AB

Callipering involves two perpendicular measurements. The rule of thumb is that where the calliper scale lay during the first measurement (left), one of the calliper jaws should lie for the second measurement (right).

Measurement results

You can see the accuracy percentage for length and diameter directly in the calliper. You also see the calibration potential, which indicates whether the measurement system needs calibration. Note that a low accuracy percentage, together with a low calibration potential, indicates a mechanical fault that cannot be corrected by calibration – you must find the malfunctioning component and replace it.

Checks of measurement equipment

You should carry out regular checks of the measurement system. Open and close the head, while checking that the diameter sensors respond. Check by feeling that the moving parts are firmly connected, and that the measuring wheel for log length can rotate and is not too worn. A large dispersion in the harvester's

Photo: Johan Heurgren Film AB

Make it a habit to carry out daily checks of the harvester head and measurement system. Make sure there are no poor connections, and remove branches and other foreign objects that may have got stuck in the head.

Photos: Johan Heurgren Film AB

It is important to regularly check the handheld instruments. The measuring tape is checked against a steel measuring tape, class 1 (left). This also applies to digital measuring tapes, which must be calibrated if the length deviates from the template. The calliper is most easily checked with a calliper template (right).

measurements probably means a mechanical fault in the equipment or incorrect settings. You should then check the harvester carefully to find the source of error.

Handheld instruments must also be checked regularly. The measuring tape is checked against a steel measuring tape, class 1, which is placed beside the measuring tape. If you are using a digital measuring tape, this must be calibrated if the check shows that it is giving incorrect length measurements. A traditional measuring tape must be replaced if it does not measure correctly. The easiest way to ensure that the calliper is showing the correct measurement is to use a calliper template with fixed control measurements. In the event of deviations, the calliper must also be recalibrated according to the manufacturer's instructions.

Continuous checks and feedback are the key to ensuring that the harvester measures really well.

Photo: Johan Heurgren Film AB

Troubleshooting

If the measurements are deviating from what is normal for your harvester, check the measurements of a few more stems.

If the measurement error continues, carry out troubleshooting checks in the following order:

1. Are there any mechanical faults in the head and measurement system? Common problems are broken diameter sensors, worn measuring wheel, poor attachment of the diameter sensor or measuring wheel, and blunt or loose delimbing knives. Replace the malfunctioning component and then check the measurement again. A new basic calibration may also be needed.
2. Are the pressure settings correct? If you need to adjust the pressure or pulsation, check the measurements on new control stems to confirm that the adjustment had the desired effect.
3. Does the measurement system need calibration? If the length and diameter measurements show a systematic error, a calibration may be necessary. In that case, make sure there is sufficient data in the computer to generate a good calibration curve in all diameter classes.

Remember to check the measurement result after every adjustment.

If you cannot find the fault, or cannot rectify it yourself, contact your service provider.

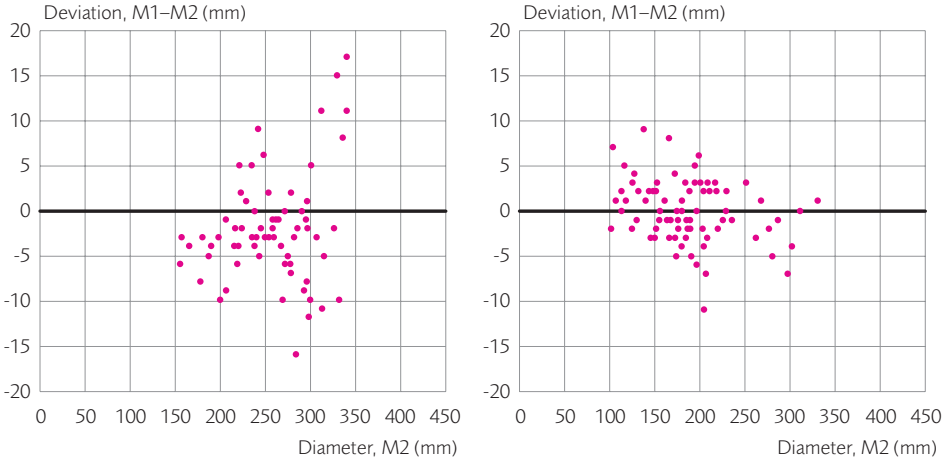


Figure 6. Effect of a mechanical fault on measurements. In the diagram to the left, the standard deviation is 6.1 mm, and 54 % of the diameter measurements are within ± 4 mm. The diagram to the right shows the same harvester after replacement of diameter sensors and bushings to the delimbing knives, followed by calibration. The standard deviation is now 3.8 mm, and 85 % of the diameter measurements are within 85 %. A marked improvement!

1. Control measurement indicates deviations from the harvester's normal measurements.
2. Check more control stems to confirm the measure ment error.
3. Troubleshoot in three steps.

Step 1 – Mechanical faults

Are the mechanical parts working correctly? Check in particular:

- The function of the diameter sensors
- The condition of the measuring wheel
- Attachments of delimbing knives, feed rollers, sensors and measuring wheel
- Connections and sharpness of delimbing knives

Correct any mechanical faults and then check whether the measurement error remains. If so, proceed to Step 2.

Step 2 – Settings

Are the harvester settings correct? Check in particular:

- The pressure on the delimbing knives and feed rollers per diameter class
- Any pulses in the pressure – pressure level, pulse period, activated diameters
- The pressure on the measuring wheel

Correct any incorrect settings and then check whether the measurement error remains. If so, proceed to Step 3.

Step 3 – Calibration

Is the measurement system correctly calibrated?

- Is there still a systematic deviation after Steps 1 and 2?
- Collect sufficient data for calibration in all diameter classes
- Calibrate in small stages rather than a large adjustment all at once

Calibrate and check the measurement. Still incorrect? Contact your service provider.

Figure 7. Troubleshooting procedure when the harvester's measurements deviate from normal.

Calibration of the harvester's measurement system

The measurement system is calibrated when necessary, to ensure that the sensors' signals correspond to the actual measurement on the stem. Calibration is needed after major changes, such as component replacement, and as continual fine-tuning to address changed conditions for measurement, such as when the bark freezes.

Before you make a decision on calibration, you must rule out that the deviation is caused by a technical fault or incorrect settings. These types of error are often shown by a large dispersion in the measurement results, and cannot be removed by calibration.

When you have decided on a calibration, you must have sufficient data available. Data is needed in all diameter classes, to avoid damaging an already good calibration by making changes in adjacent classes.

The amount of adjustment to the system in a calibration can either be calculated automatically by the on-board computer or you can feed the information in manually. When the computer proposes large adjustments, it can sometimes be a good idea to implement them in small stages, and not accept the entire proposal all at once.

There are two main types of calibration for diameter measurement:

- **Breakpoint calibration**, where every diameter class is calibrated separately (adjacent diameter classes are also affected to a certain extent).
- **Regression calibration**, which converts all the data to a straight line.

Particularly with regression calibration, data must be available for both small and large diameters, to prevent the calibration curve changing too much at the peripheries. The length is usually calibrated with a correction factor, so that the signal from the measuring wheel's pulse sensor corresponds to the forward-fed log length. Extra care should be taken when the temperature is changing rapidly. The penetration of the measuring wheel into the bark can vary drastically in just a few hours, which can produce a large systematic measurement error.

A special correction can also be made for length measurement in the butt part of the stem, to compensate for butt swelling and deviating bark, and thereby avoid producing butt logs that are too short.

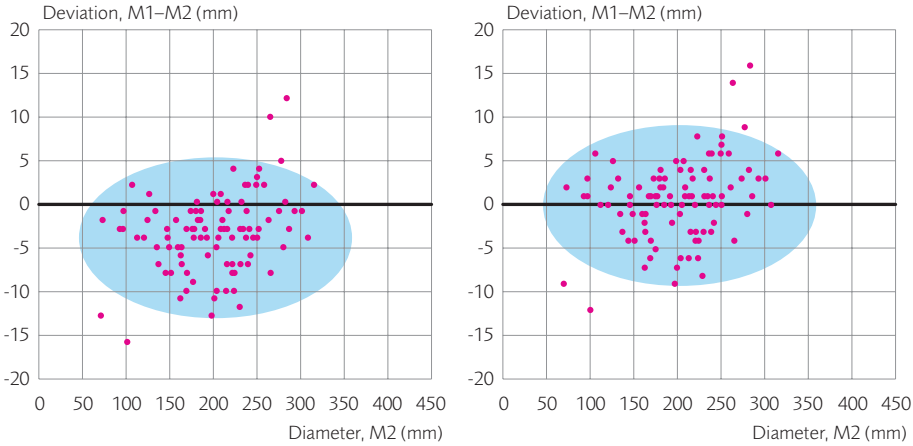


Figure 8. This harvester measures 64% of the diameters within ± 4 mm from the manual control measurement. The standard deviation is 4.2 mm, while the systematic error is no less than -3.7 mm (left picture), indicating that the measurement system must be calibrated. By adjusting all diameter classes upwards by 3.7 mm, the harvester would, in theory, measure 76 % of the diameters within +/- 4 mm (right picture). If, in addition, you were to recalibrate the entire base curve on the basis of the median in every diameter class, the harvester would, in theory, measure 79 % of the diameters within ± 4 mm. Such a calibration would enable the harvester to measure very accurately.

Take great care when measuring length and diameter manually, as this is the key to good measurements by the harvester.

Suitable stems for calibration

- The calibration data should include values in all diameter classes.
- Stems that have too many thick branches or that are oval are unsuitable for use as calibration data, as they give unreliable values. The same applies for stems with a lot of bark worn off, or stems where you suspect that the harvester has not measured properly.
- For the smaller diameter classes, thinner stems are preferable to top sections, which are usually more difficult to measure because of branches.

The randomly selected control stems that meet the requirements can form the basis of the calibration data. These are then supplemented later if necessary with operator-selected stems.

In a major calibration, such as after a component replacement, you should leave the cab and select stems for calibration, as it is often difficult to see how round a stem is from the cab. Also, make sure that the data you are using in calibration is not too old, and that it corresponds to the conditions in which you are currently working. You should also remove the existing stems in the database, to avoid calibrating on incorrect data.

Photo: Jonas Hemmingsson, VMF Syd

For a major calibration, it is recommended that you get out of the cab to select calibration stems. This makes it easier to determine stem roundness.

Glossary

- **Control stem** – Stem selected for manual control measurement for quality assurance and/or calibration.
- **Randomly selected stem** – Stem selected by the on-board computer for control measurement within the quality assurance system on the basis of a pre-set random frequency.
- **Operator-selected stem** – Stem selected manually by the harvester operator for control measurement, which often provides the data for calibration.
- **Calibration stem** – Stem selected for manual control measurement to provide the data for calibration.
- **Quality assurance** – Method for continual internal checks of the harvester's measurement, based on manual control measurement of randomly selected stems. The quality assurance system for the harvester's measurement also includes a certified auditor, who monitors the quality-assured harvesters and gives the harvester team continual feedback. The auditor also visits the harvester teams in the field at least twice a year.


JOHN DEERE

skogforsk.se

Uppsala Science Park, 751 83 Uppsala. Tel. +46 (0)18-18 85 00
E-post. info@skogforsk.se www.skogforsk.se