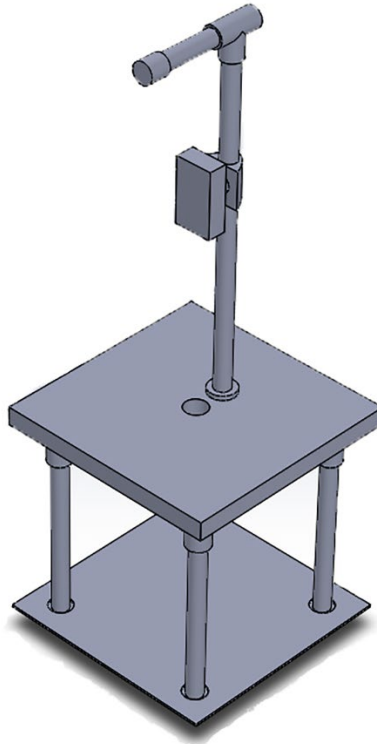


Turf Height Tester

Construction and Assembly Instructions (updated May 29, 2020)



For additional device information, see
Patton, A.J. and R.C. Braun 2021. Measurement of turf height and growth using a laser distance device.
Crop Science In press. <https://doi.org/10.1002/csc2.20295>

Assembly requires the use of power tools including saws. Improper usage of any given tool can lead to injury and the potential to lose a finger or eye in severe circumstances. Thousands of emergency room visits occur every year from accidents involving hand and power tools. Proper safety measures and PPE reduce the risk of injury. Use recommended PPE inclusive of eye protection when using a drill, saw, or a variety of other tools – powered and non-powered.

Tools Required for Assembly

- Pencil
- Drill
- Drill bit – 3/32" or similar for pilot holes
- Crescent wrench
- Hole saw drill bit – 1" for table and platform holes
- Box knife or razor blade
- Square
- Allen wrench (5/32")
- Miter saw (others saws may substitute)
- Circular saw (table or jig saw may substitute)
- Tape measure
- Phillips screwdriver (recommend cordless)
- PVC primer and glue

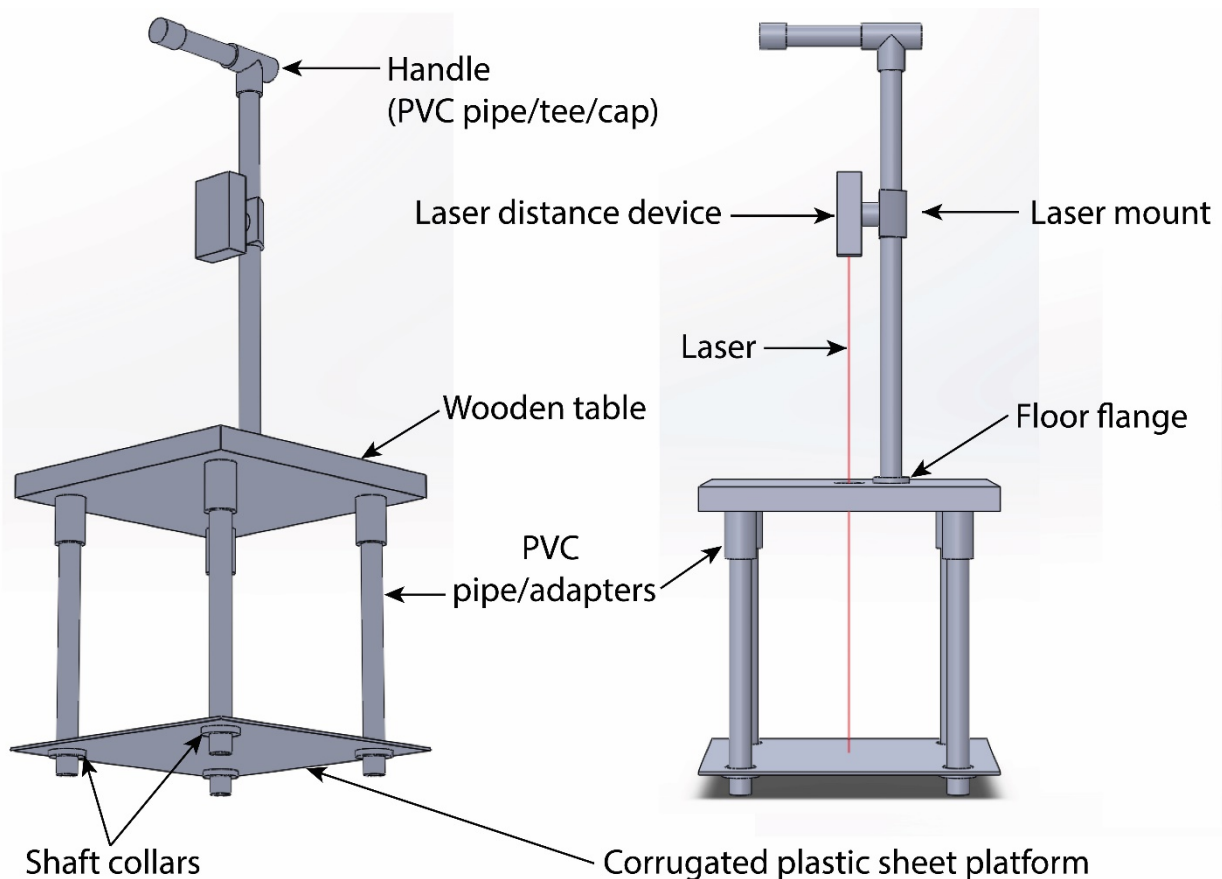


Figure 1. A table with a floating platform, carrying arm (handle), and a mounted laser distance measurement instrument developed to measure turf sward height. Components listed in Table 1.

Table 1. List of components (parts) needed to construct the Turf Height Tester and their costs. The device was constructed using readily available construction materials.

Item	Description	Company/Vendor	Quantity	Cost Each	Total Cost
Laser mount	CMP227, bicycle handlebar mount with SBH camera adapter plate	Arkon/Amazon	1	\$11.88	\$11.88
Corrugated plastic sheet	0.4 × 30.5 × 30.5-cm cut to size from a 61 × 91 cm Twin Wall Plastic Sheet	Coroplast/Hardware Store	1	\$10.98	\$10.98
Steel shaft collar	22.2 mm (7/8-inch) bore diameter, C-087 with set screw	Climax Metal Products Company/Grainger	4	\$2.61	\$10.44
PVC pipe	12.7-mm (0.5-inch) SCH 40 PVC ^a , length 5'	Charlotte Pipe/Hardware Store	2	\$1.41	\$2.82
Floor flange	12.7-mm (0.5-inch) galvanized floor flange, item# 311 F-12	LDR Industries /Hardware Store	5	\$3.78	\$18.90
PVC male adapter	Schedule 40, 1/2 Slip ^a (12.7-mm) x NPT Male, item# 436-005	NIBCO/Hardware Store	5	\$0.28	\$1.40
PVC tee	Schedule 40, 1/2" (12.7-mm) Slip PVC ^a Pipe Tee, item# 401-005	NIBCO/Hardware Store	1	\$0.29	\$0.29
PVC cap	Schedule 40, 1/2" (12.7-mm) Slip PVC ^a Pipe Cap, item# 447-005	NIBCO/Hardware Store	1	\$0.19	\$0.19
Wooden table	1.8-cm hardwood cut to 30.5 x 30.5-cm with 3.2-cm drilled center	Hardware Store	1	\$6.00 ^b	\$6.00
Screws	#10 x 3/4 in. Phillips Flat Head Zinc Plated Wood Screw	Hardware Store	20	\$0.08	\$1.60
Laser distance measure	Bosch Bluetooth Enabled Laser Distance Measure with Color Backlit Display GLM 50 C	Bosch/Amazon	1	\$102.00	\$102.00
Total					\$166.50

[†] Nominal measurement. The 1/2" PVC pipe had an external diameter of 21.5 mm.

[‡] Several different materials could be used for this component.

Step 1. Purchase necessary components (parts) and gather necessary tools.

HINTS:

- Most hardware stores will sell PVC in 5 ft increments. Buy two 5 ft lengths or one 8 ft length.
- For the wooden table, you'll likely need to buy a larger piece of wood and cut it down to size (12 in x 12 in). Remember that wood is sold in nominal sizes. For example, if you buy a 1 x 12 x 3 ft Red Oak Board, the actual size is 0.75 in x 11.25 in (or 11.5 in) x 3 ft. As such, you may need to buy a 1 in x 16 in x 3 ft Red Oak Board (Actual Size $\frac{3}{4}$ in x 16 in x 3 ft). Later, you will cut it down to the proper 12 x 12 in length by width.
- For the corrugated plastic sheet, you can buy 18 x 24 in Corrugated Plastic Sign Blank- White often found near the garage sale/for sale signs in the hardware store. Later, you will cut it down to the 12 x 12 in length by width with a razor blade.

Step 2. Cut the Schedule 40 PVC pipe to length. I recommend using a miter saw but several types of saws could be used for this application. Cut the following lengths.

- 4 pieces at 10.5 inches in length. It is important that each of these 4 pieces is the exact same length.
- 1 piece at 18 inches in length (This piece will be used for the handle. It can be longer if you are taller or shorter. You can cut this piece later in step 11 after dry fitting the piece to your preference)
- 1 piece at 4 inches in length

Step 3. Cut a piece of wood to serve as your 12 x 12 inch length by width table. See NOTES above in step 1 on the materials. I recommend using a table saw but several types of saws could be used for this application including a sliding miter saw or a jig saw.

Step 4. Drill hole in the center of the wood table. Use a ruler from corner to corner to mark an X in the center (Figure 3). A Forstner bit 1 to 1.5 inches in diameter is recommended (cleaner cut) but a hole saw or speed bit will also work (Figures 4-5).



Figure 3. Mark the center of the board.



Figure 4. Select a drill bit 1" or more in size.



Figure 5. Drill the hole. **Step 5.** Cut a 12 by 12 inch piece from a corrugated sheet (see Step 1) (Figures 6-8). Make sure the piece you select is nice and flat with no bows, warp, or twist. Use a ruler to mark out the area. Also use a ruler to guide the razor blade in making a straight cut. After cutting assess the trueness/flatness of the piece by placing it on a flat surface and inspecting the corners and centers to make sure they rest flat on the surface. After checking one side with this method, flip the piece over and recheck for flatness (see video). Lastly, using a ruler, mark the center of the piece with an X similar to how you did with the wooden platform in Figure 3.

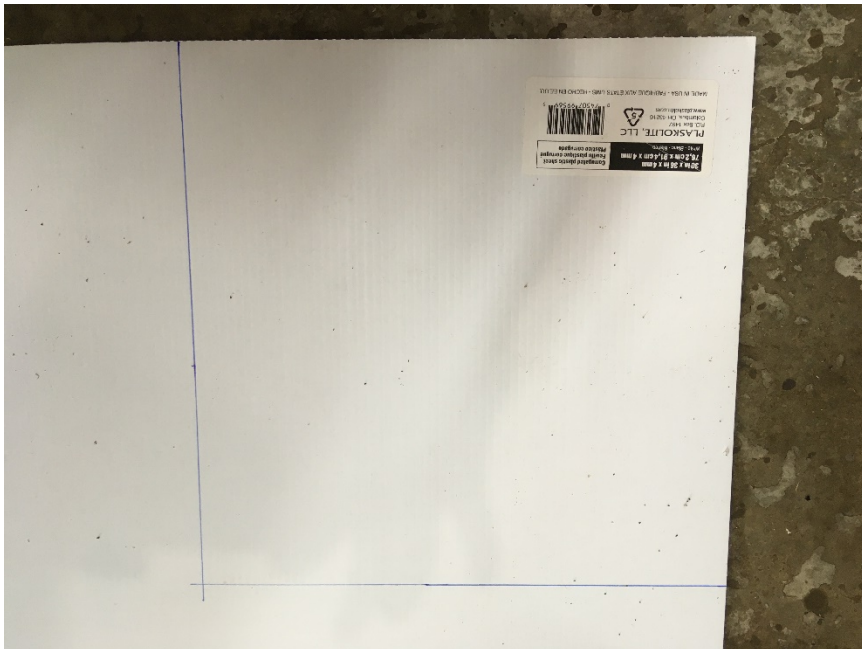


Figure 6. Mark a 12 by 12 inch square using a pencil or fine marker.



Figure 7. Use a ruler to guide your cutting with a razor blade.



Figure 8. You may need to cut several pieces in order to get one perfectly flat/true.

Step 6. Assemble PVC legs by gluing (PVC primer and cement) one PVC male adapter (Schedule 40, 1/2 Slip (12.7-mm) x NPT Male, item# 436-005) to one 10.5 inch length of PVC pipe (12.7-mm (0.5-inch) SCH 40 PVC). Repeat this process for all four legs (see video).

Parts needed	Schedule 40, 1/2 Slip (12.7-mm) x NPT Male, item# 436-005	10.5 inch length of PVC pipe (12.7-mm (0.5-inch) SCH 40 PVC)
		

Step 7. Attach floor flange (12.7-mm (0.5-inch) galvanized floor flange, item# 311 F-12) to the bottom (which ever side of the wooden table you decide) by aligning four floor flanges in the corners of the 12 x 12 in wooden piece (1 in each corner). Align the edge of each circular flange to the edge of the piece of wood. Mark the 4 holes in each floor flange with a pencil. Pre drill holes (0.5-inch deep) using a 3/32 inch drill bit or similar. Use #10 x 3/4 in. Phillips Flat Head Zinc Plated Wood Screws to affix each flange.

Parts needed	12.7-mm (0.5-inch) galvanized floor flange, item# 311 F-12	#10 x 3/4 in. Phillips Flat Head Zinc Plated Wood Screw
		

Step 8. Thread on the legs you created in step 6 to the floor flanges attached in step 7. Thread carefully so not to strip the threads in the plastic to metal connection. Thread each leg hand snug but not overly tight. Next, check that each leg is perpendicular to the table top. You can use a level to help with this. If perpendicular, next, loosen slightly or tighten slightly each leg so that the “table” you have created sits perfectly level on a smooth level surface without wobbling. Fix the wobble by tightening or loosening the legs to change their lengths slightly until the table sits firm and level.

Step 9. Place the table on top of the corrugated plastic that was cut in step 5. Align the table over the plastic so there is equal spacing between each leg and each corner of the corrugated plastic. When aligned uniformly across all four corners, trace the outline of the PVC legs with a pencil onto the plastic sheet (Figure 9). This will provide the markings you’ll use to cut four holes in the corrugated sheet. Also, at this time mark one of the corners of the platform and on the same corner mark the wooden platform. This will allow you to realign the platform in the some orientation later. Now, use a hole saw to cut out “slides” for the table legs (see Figures 10-13).

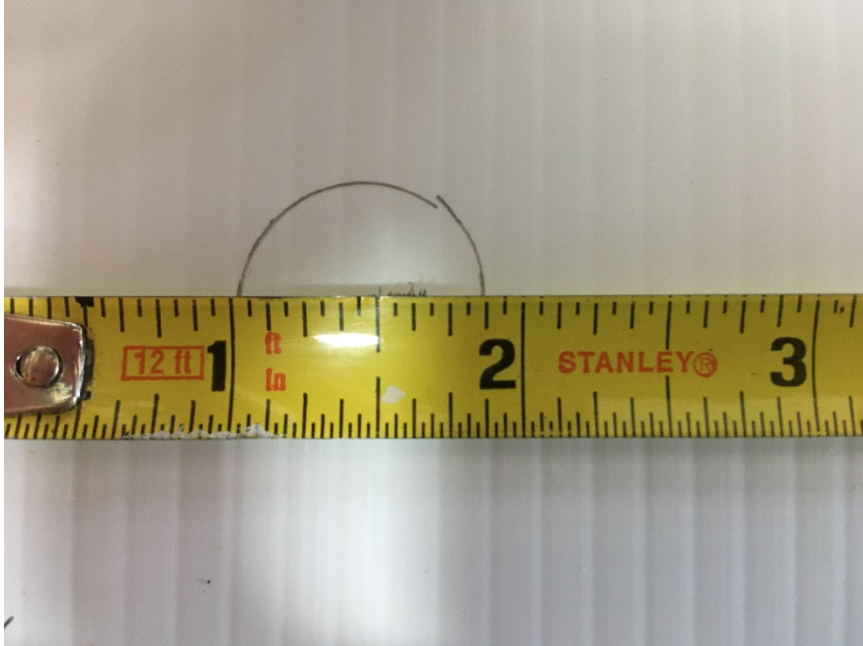


Figure 9. The outline of each leg should be approximately 0.875 inch (21.5 mm).

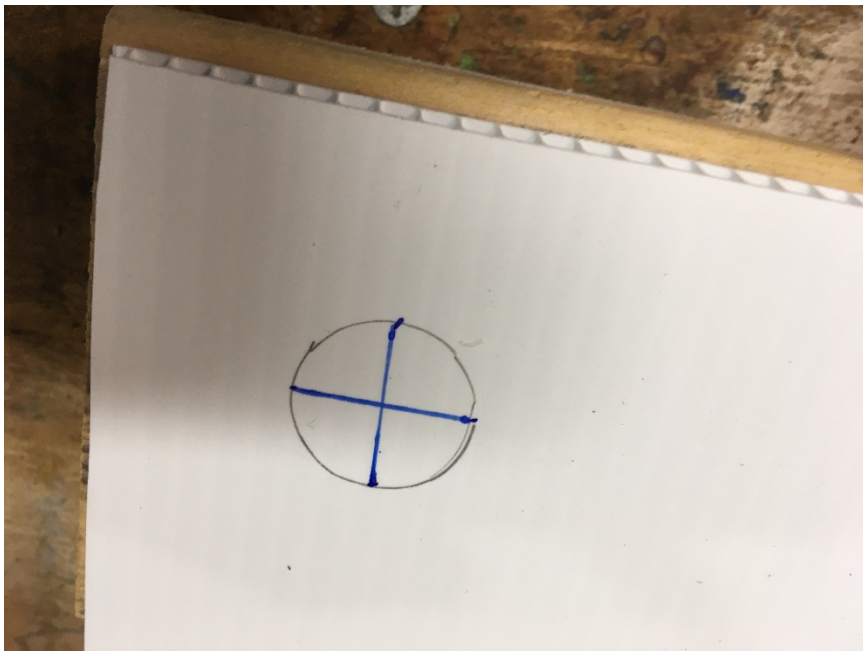


Figure 10. Mark the center of the hole to aid in cutting.



Figure 11. Use a hole saw drill bit 1.125 or 1.25 inches in diameter.



Figure 12. Carefully drill out each corner marked. Place a scrap piece of wood below the cut to keep from bending the platform and to help provide a cleaner cut.

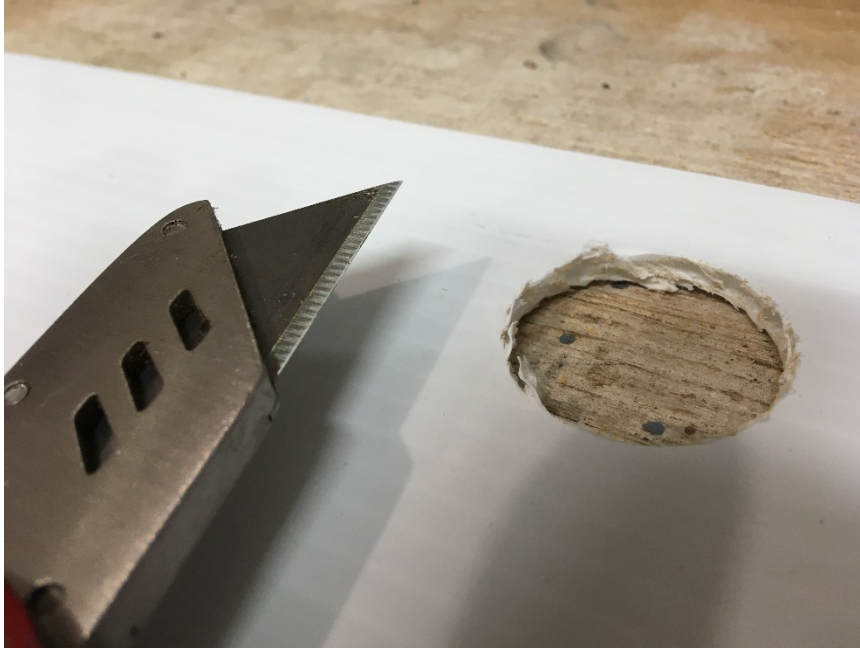







Figure 13. Using a razor blade, trim any plastic “burs” that might stick up or down or might causing friction on the PVC legs.

Step 10. Insert the platform over the legs keeping the orientation correct (marked corner of the platform oriented with the marked corner of the table – from step 9). Install a 22.2 mm (7/8-inch) bore diameter shaft collars (C-087) with set screw over the bottom edge of each PVC leg. The shaft collars keep the platform from falling off when transporting the tester or when moving from one plot to the next. Mark each leg at approximately 1.0 inch from the bottom. Insert the shaft collar to that mark and tighten the set screw firmly with a 5/32 Allen wrench to hold the shaft collar in place.

Parts needed	22.2 mm (7/8-inch) bore diameter, C-087 with set screw
	

Step 11. Assemble arm (i.e. handle) inclusive of attaching laser mount. Assemble PVC arm by first dry fitting all the pieces. See the drawing of the “handle” for reference. For part 1, glue (PVC primer and cement) one PVC male adapter (Schedule 40, 1/2 Slip (12.7-mm) x NPT Male, item# 436-005) to one 18-inch length of PVC pipe (12.7-mm (0.5-inch) SCH 40 PVC). For part 2, glue the end cap to one end of a 4-inch PVC pipe. Attach the other end of the 4-inch PVC pipe to the Slip PVC^a Pipe Tee. Before gluing

parts 1 and 2 together, slide the bicycle handlebar mount over the top of the longest PVC pipe piece (part 1). Lastly, glue parts 1 and 2 together by gluing part 1 to the bottom of the tee in part 2.

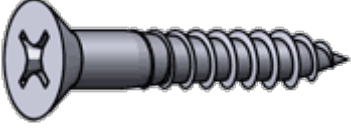
Parts needed	CMP227, bicycle handlebar mount with SBH camera adapter plate	18-inch and 4-inch lengths of PVC pipe (12.7-mm (0.5-inch) SCH 40 PVC)	Schedule 40, 1/2 Slip (12.7-mm) x NPT Male, item# 436-005	Schedule 40, 1/2" (12.7-mm) Slip PVC Pipe Tee, item# 401-005	Schedule 40, 1/2" (12.7-mm) Slip PVC Pipe Cap, item# 447-005
					

Step 12. Attach the Bosch Bluetooth Enabled Laser Distance Measure with Color Backlit Display GLM 50 C to the CMP227, bicycle handlebar mount with SBH camera adapter plate with the threaded stud on the handlebar mount.

Step 13. Thread the assembled arm in step 11 to the remaining floor flange. Without screwing the floor flange to the top yet, dry fit the floor flange onto the top of the wooden table. Locate the flange adjacent to the hole near the center of the board. Turn on the laser. You'll want to make sure the handle on the arm is pointed towards the center (see drawing) and the laser and handlebar mount are adjusted to shoot the laser through the approximate center of the wooden table and then hitting the X marked on the top center of the plastic platform. Use a level to help make sure things are approximately square/perpendicular.

Parts needed	12.7-mm (0.5-inch) galvanized floor flange, item# 311 F-12
	

Step 14. Once the laser is positioned, mark the holes in the floor flange with a pencil. Predrill the holes and attach the floor flange with four #10 x 3/4 in. Phillips Flat Head Zinc Plated Wood Screws.

Parts needed	#10 x 3/4 in. Phillips Flat Head Zinc Plated Wood Screw
	

Step 15. Setup – Remove the shaft collars, set the tester with the plastic platform on a flat laboratory bench or worksurface clear of debris. Turn on laser, get a bench measurement, which is the measurement of the device with the platform on the flat surface and the shaft collars removed. Write the measurement with sharpie on the platform as you’ll need to reference this measurement to determine the height of the turf. Reinstall shaft collars

Step 16. Your now finished (Figure 14)! See use instructions for operation.

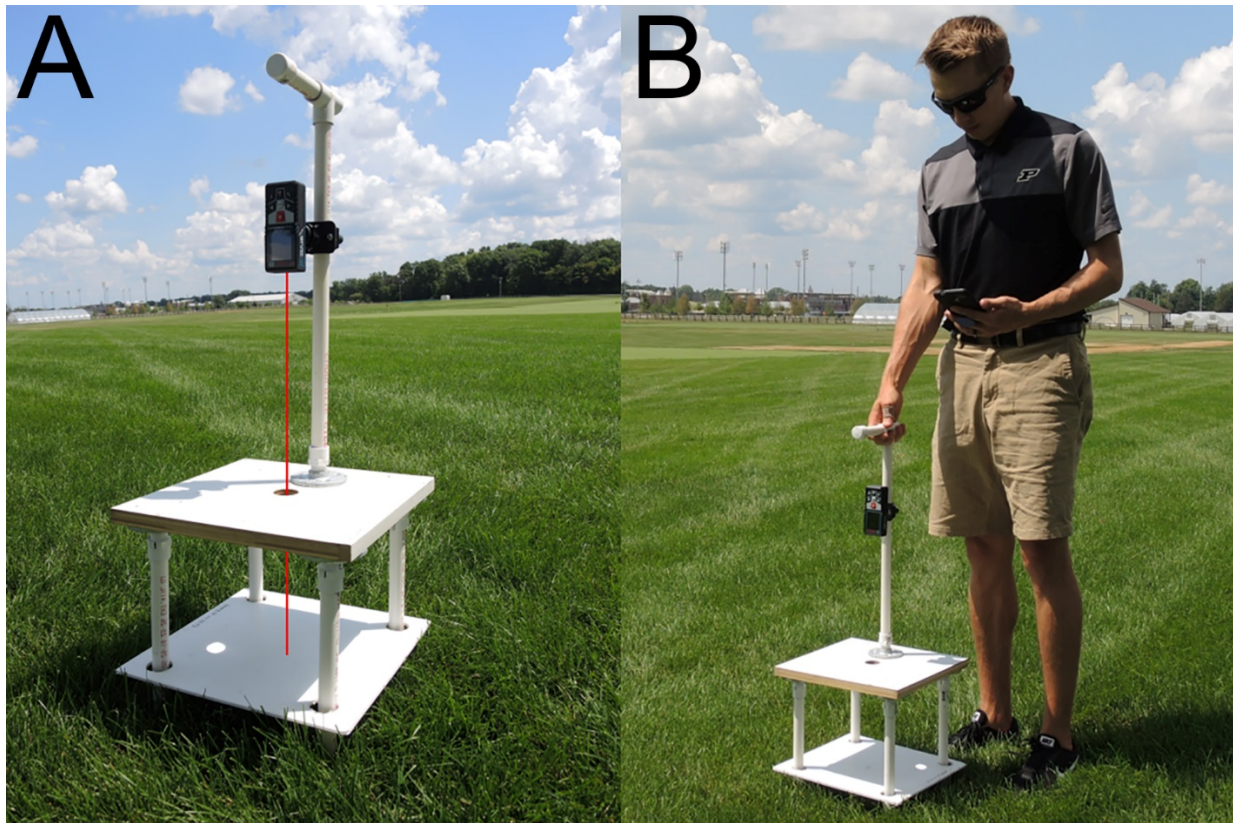


Figure 14. Finish product. Photographs of the Turf Height Tester, which has a table with a floating platform, carrying arm, and a mounted laser distance measurement instrument developed to measure turf sward height is shown with a drawn laser beam (A) and in use collecting data using Bluetooth and a mobile device (B).