Reliability of Height and Diameter Remeasurements on Red Pine *(Pinus resinosa* Ait.) Seedlings

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A study was conducted to determine the error associated with remeasurement of diameter and heights of red pine (Pinus resinosa *Ait.) seedlings by the same and different observers. There were no significant differences between initial measurements and remeasurements of seedling height, either by the same or different observers. A major source of error in seedling diameter measurements is correct placement of the calipers on the stem. By marking the measurement point with an indelible felt-tip pen, the remeasurement error between two observers was significantly reduced.*

Many studies involving the effects of various treatments on seedling survival and growth use repeated measurements of height and diameter (1,4). After establishing a starter fertilizer study involving repeated annual height and diameter measurements of nearly 1,000 seedlings, we became concerned about the reliability of the measurements. The study would certainly not be effective if treatment differences between seedling heights and diameters were masked by variability associated with the measuring process. This variability would also be increased if different individuals were engaged in the measuring process.

One way of reducing measurement errors of seedling root collar diameters is to permanently mark the seedling at the point of measurement, because placement of the calipers on the stem can be a major source of error. Consistent orientation of the calipers is fairly simple, requires no extra time, and also reduces error. The act of marking the stem is, however, quite time-consuming, and a question arose as to whether or not the time investment was worthwhile. The objectives of this study were to determine if significant differences exist a) between repeated diameter measurements of unmarked and marked seedling stems, using the same observer and different observers and b) between repeated seedling height measurements using the same and different observers.

Methods

In May 1984, 25 freshly planted 3+0 red pine seedlings were isolated to serve as a representative sample. From previous work we determined that height and diameter measurements on a sample of 25 seedlings would allow us to estimate within ± 5 to 10 percent of the population mean, using the 95-percent level of probability (3).

On each seedling the root collar diameter or the diameter at the soil surface (if the root collar was not visible) was measured to the nearest 0.02 millimeter using a set of calipers. The measurements were made by the two independent observers, first on unmarked seedlings, then on seedlings with the measurement point marked with a red ring using an indelible felt-tipped pen. All measurements were repeated. Seedling heights were also measured by the same observers. The duplicated height measurements were recorded to the nearest centimeter.

Statistical analyses were conducted using paired t-tests at 5 percent probability (2). For both diameter and height, two statistical tests were calculated. For diameter, the first test was for a difference between repeated measurements by the same observer on unmarked seedlings and on marked seedlings. The second test was for a difference between repeated measurements by observers 1 and 2 on the unmarked seedlings and then on the marked seedlings. The tests for height involved differences between repeated measurements by the same observer and repeated measurements by different observers. For testing purposes the following null hypotheses were established:

Diameter

(1) H_o: D1 = D2

where D1 = mean of differences between repeated measurements of unmarked seedlings (observer 1); and

D2 = mean of differences between repeated measurements of marked seedlings (observer 1).

(2) H_o: D3 = D4
where D3 = mean of differences between measurements of unmarked seedlings by observers 1 and 2 and

D4 = mean of differences between measurements of marked seedlings by observers 1 and 2.

Height

(1) H_o: H1 = H2
where H1 = mean height of seedlings as first measured by observer 1 and

H2 = mean height of seedlings measured by observer 1 in second run.

(2) H_o: H1 = H3
where H3 = mean height of seedlings as measured by observer 2.

Table 1—*Results of paired t-tests for diameter and height measurements*

Null hypothesis	Alternate hypothesis	Means	Calculated test statistics	Result of test
H_o: D1 = D2	H_a: D1 ≠ D2	D1 = 0.18 mm D2 = 0.13 mm	1.532	Accept H_o
H_o: D3 = D4	H_a: D3 ≠ D4	D3 = 0.29 mm D4 = 0.14 mm	2.955	Fail to accept H_o
H_o: H1 = H2	H_a: H1 ≠ H2	H1 = 20.16 cm H2 = 20.24 cm	0.811	Accept H_o
H_o: H1 = H3	H_a: H1 ≠ H3	H3 = 20.36 cm	1.879	Accept H_o

Results and Discussion

The results of the paired t-tests and the means used in the tests are presented in table 1. The tests show that when the same observer is making diameter measurements, there is no benefit in marking the point of measurement on the seedling stem. Although the mean difference between marked and unmarked stems was lower (0.13 compared to 0.18 millimeter), the reduction was not significant at P = 0.05. When a different observer is making the measurements, however, marking the measurement point significantly reduced the error. The mean difference between measurements made by observers 1 and 2 without marking was 0.29 millimeter, and with marking it was 0.14 millimeter.

Measurements of seedling height have very little error associated with them. Repeated measurements by the same observer and measurements by different observers were not significantly different, indicating that height growth measurements are probably the most reliable for assessing treatment differences.

Conclusion

In studies in which measurements of seedling heights and diameters are used to assess treatment effects, marking the diameter measurement point on the seedling stem can significantly reduce remeasurement error if a different observer is making the remeasurement. An indelible felt-tipped pen ring on the stem will remain visible for about a year in Wisconsin and should be reestablished at each annual measurement. If the same observer is making the diameter measurement, with careful caliper alignment the marking ring may not be necessary.

Seedling height measurements can be made with greater ease and lack of remeasurement error, especially with different observers. Repeated measurements of height to obtain growth rates would provide the variable with the least error.

Literature Cited

1. Carlson, W.C.; Preisig, C.L. Effects of controlled release fertilizers on the shoot and root development of Douglas-fir seedlings. Canadian Journal of Forestry Research 11: 230-242; 1981.
2. Freese, F. Elementary statistical methods for foresters. Agric. Handb. 317. Washington, DC: U.S. Department of Agriculture; 1967. 87 p.
3. Johnson, J.E.; Haag, C.L. Sample size for evaluating treatment effects on red pine seedlings. Tree Planters' Notes 35: 14-15; 1984.
4. Yawney, W.J.; Schultz, R.C.; Kormanik, P.P. Soil phosphorus and pH influence the growth of mycorrhizal sweetgum. Soil Science Society of America journal 46: 1315-1320; 1982.