MEASURING SOUTHERN PINE SEED QUALITY WITH A CONDUCTIVITY METER--DOES IT WORK?

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Abstract.--Preliminary tests of an ASA-610 Automatic Seed Analyzer from Agro Sciences, Inc. with five species of southern pines indicate that valid estimates of seed quality are possible from leachate conductivity measurements. Several factors which influence the results are discussed. Studies still in progress are expected to bring measurement errors to within acceptable limits.

Additional keywords: Germination, seed tests, loblolly pine, slash pine

Of all the methods proposed to measure seed quality in recent years, one has become the basis for commercial development of equipment to do the job. The machine used in this process is the ASA-610 Automatic Seed Analyzer, developed and marketed by Agro Sciences, Inc. of Ann Arbor, Michigan.[2/] This machine measures the electrical conductivity of water in which a seed has been soaked. The amount of current passing through the soak solution is influenced by the amount of solutes leaching from the seed, which, in turn, is theoretically related to the vigor of that seed as a function of membrane integrity. This is a non-destructive test, and the seeds can be subsequently germinated or dried for storage.

It is assumed that as a seed deteriorates, its membranes break down and allow the leaching of internal substances. Murphy and Noland (1982) found that heat-killed embryos of sugar pine had higher rates of solute leakage than did viable ones, and Pitel (1982) demonstrated that increasing periods of accelerated aging of jack pine seeds resulted in increased conductivity of the soak water. Hocking and Etter (1969) reported a close correlation between germination of white spruce and the sugar concentration in seed leachate. The relationship of leached solutes and field emergence was first demonstrated for peas in 1968 (Matthews and Whitbread 1968). Later research has supported the principle, and the International Seed Testing Association has included an electrical conductivity test in its Handbook of Vigor Test Methods (ISTA 1981).

The first machine marketed by Agro Sciences to measure seed quality used a forcep-type electrode system which measured current passing through a single seed. The ASA-610 now on the market has a multiple-electrode plate which fits onto a tray with 100 uniform compartments for soaking the seed sample (usually one seed per compartment). When the plate is placed on the tray, the

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electrode pairs are immersed in the soak solutions. The ASA-610 then measures the individual current levels in 100 seed compartments simultaneously.

This new model has shown great promise with agricultural seeds (McDonald and Wilson 1979). The potential value of such a method for quick estimates of the seed quality is enormous. An ASA-610 was acquired for the Forestry Sciences Laboratory in 1981, and tests were begun on southern pine seeds.

MATERIALS AND METHODS

The basic approach to evaluation of the ASA-610 was to draw samples from a wide variety of seed lots, take conductivity readings, and then germinate these same seeds in the laboratory. Seed lots over a wide range of ages (collected 1967 to 1981) from throughout much of the native range of the species were used. Tests were carried out on 25 lots of loblolly, 25 of slash, 6 of shortleaf, 7 of longleaf, and 4 of eastern white pine.

Several factors influence the current readings in the solutions: (1) amount of soaking time, (2) temperature of the solution, (3) water level in the measurement cells (seed:water ratio), and (4) initial seed moisture content. After extensive preliminary testing, the following conditions were selected for standardization of measurement technique:

(1) soaking time - 48 hours
(2) solution temperature - 25±1°C (laboratory temperature)
(3) water level - cells uniformly full (4 ml deionized water)
(4) initial seed moisture content - 10 to 12% or lower (only dry seed lots from storage were used).

There were two approaches to evaluation:

(A) Individual Seed Response - Conductivity measurements for individual seeds were related to the number of days required for germination of those seeds. Conductivity measurements were taken on two samples per lot. These seeds were then germinated in cabinet germinators set for the standard 20°/30°C alternating regime (AOSA 1981). Leachate conductivities were recorded on tape, and seed identities were maintained during the germination tests. Simple correlation coefficients were calculated.

(B) Entire Sample Response - As in germination testing, response of a suitable sample is more likely to reflect the condition of the population as a whole than are measurements on individual seeds. One approach suggested by the manufacturer is to set a threshold value of cell conductivity. These values are called "partition values," and they theoretically separate live and dead seeds. Partition values usually vary among species and must be chosen empirically. By plotting the frequency distribution of individual seed conductivities and comparing these data to germination results, trial partition values were chosen. In subsequent tests, the meter was set on these partition values, and the readout gave the number of seeds whose conductivity was lower than the partition value.

In addition to partition value estimates, mean conductivity of the 100-seed samples and the standard deviation about the mean (a measure of uniformity) were related to the germination response of the samples from each lot by linear regression. Germination tests were done in accordance with the rules of the Association of Official Seed Analysts, which establishes standard seed testing procedures (AOSA 1981).

RESULTS

(A) Individual Seed Response - This approach proved fruitless. The scatter of a typical sample (figure 1) shows the poor relationship between leachate conductivity and speed of germination. All correlation coefficients were extremely low and non-significant at the 5 percent level.

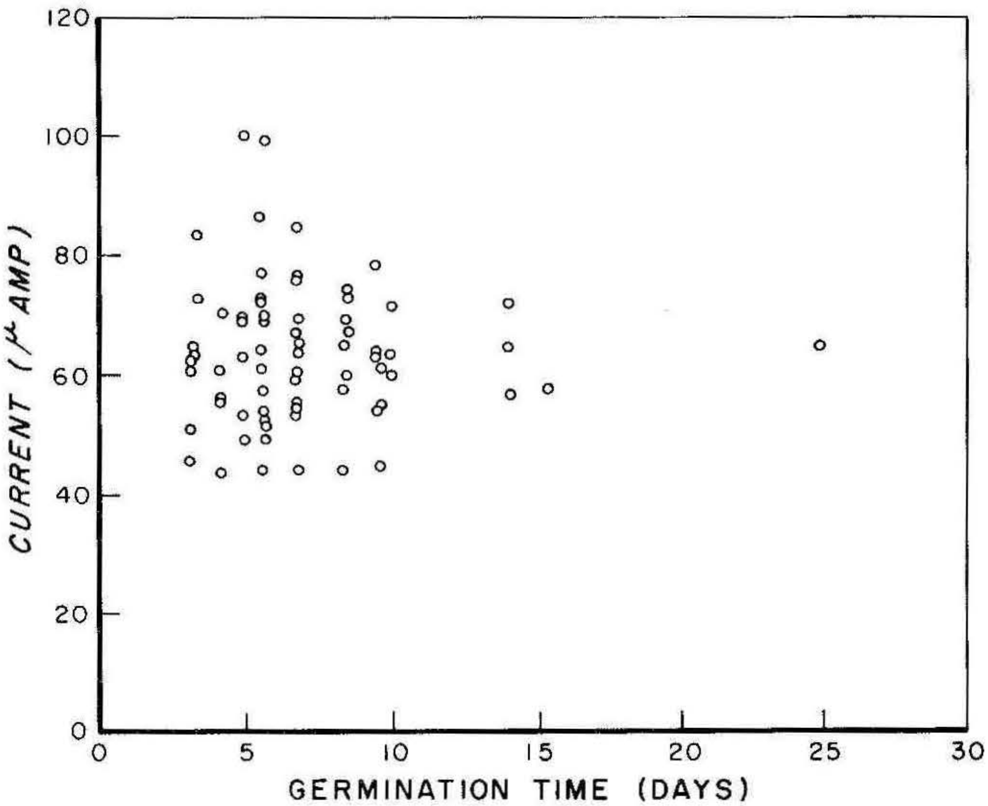

Figure 1.--Relationship of leachate conductivity and the number of days until germination for individual seeds of slash pine.

(B) Sample Response - For loblolly and slash pines, conductivity readings (mean of duplicate samples of 100) were significantly correlated with laboratory germination. The relationship was much stronger in slash, where an r value of -0.8939 was obtained for laboratory germination and mean conductivity (figure 2). This same comparison gave an r value of -0.6502 for loblolly (figure 3).

For shortleaf, longleaf, and eastern white pines, too few lots were available to make these analyses, but a summary of the data suggests that a similar relationship may exist (table 1).

Graphic analysis of the data was used to pick the most likely partition values for loblolly and slash pines. Rearrangement of the germination data in descending order facilitates this comparison (table 2). It can be quickly

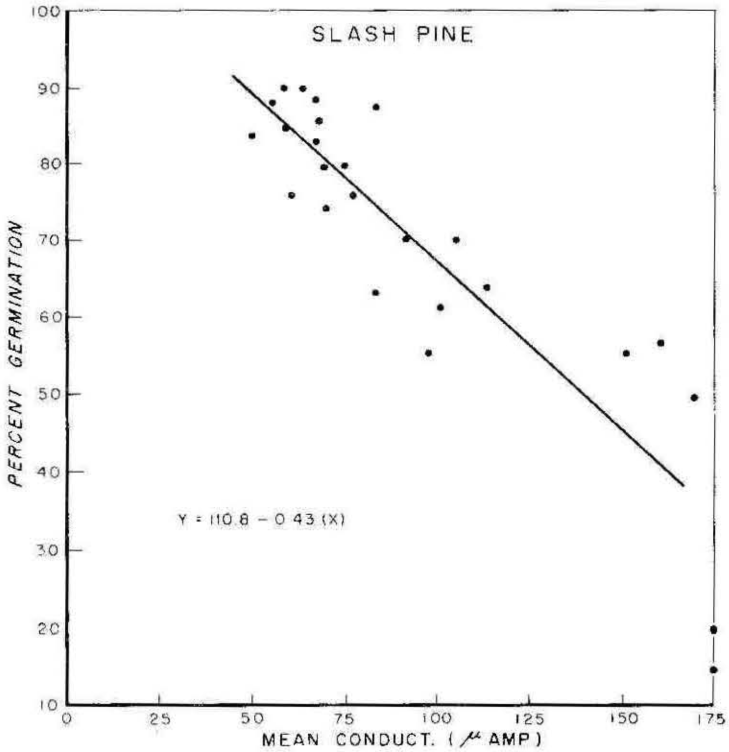

Figure 2.--Relationship of laboratory germination to mean leachate conductivity for 25 lots of slash pine. Each value is the mean of two replicates.

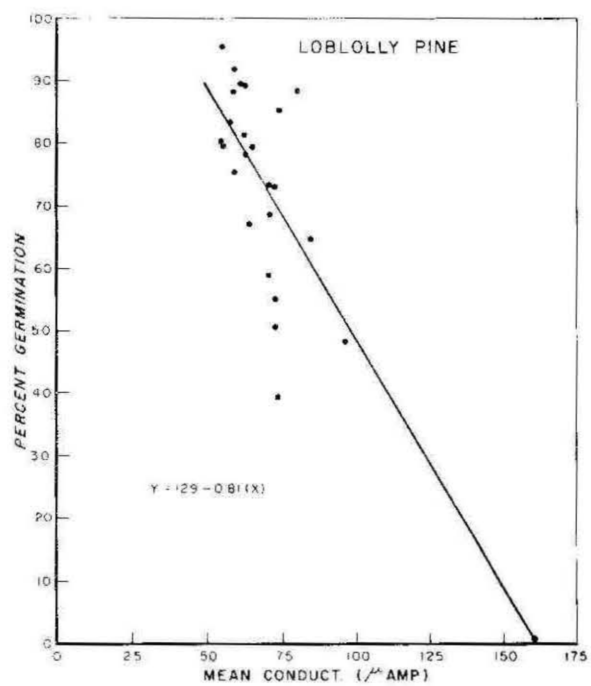

Figure 3.--Relationship of laboratory germination to mean leachate conductivity for 25 lots of loblolly pine. Each value is the mean of two replications.

Table 1. Relationship of laboratory germination to conductivity of seed leachate for three pine species. Each value is the mean of two replications

	Laboratory germination	Mean conductivity	Standard deviation of conductivity
	percent	microamp	microamp
Shortleaf	70	43.1	22.1
	68	44.4	18.4
	63	48.0	20.8
	44	43.2	13.3
	4	43.2	9.4
	2	43.2	7.8
Longleaf	84	101.4	95.6
	68	93.4	95.6
	68	103.5	99.3
	58	153.0	134.8
	38	156.5	127.6
	18	220.0	160.2
	10	355.0	203.6
Eastern white	44	59.6	45.5
	34	72.0	49.6
	18	56.6	34.0
	10	132.8	70.2

seen that the ASA-610 did a better job of predicting slash than loblolly germination. Loblolly germination was overestimated, particularly in the poorer lots. The loblolly seeds were not stratified prior to germination testing, however, and this fact may have contributed to the overestimation.

To test the choice of partition values for these two species, the measurements were reported on 25 lots of each. Of the 25, 13 lots of loblolly and 20 lots of slash were repeaters from the first test. This time the loblolly received 28 days of stratification at 3°C between conductivity measurements and germination. Four samples of 100 seeds each from 50 lots (loblolly and slash) were also planted in randomly-placed rows in the Forestry Sciences Laboratory experimental nursery in a vigor evaluation test which purposely creates stressful conditions. Emergence was counted weekly for 6 weeks.

Results of this second test supported those of the first, and this time loblolly performance was much better correlated with the conductivity measurements. As before, however, germination of the best loblolly lots was slightly underestimated, while that of the poorer lots was overestimated (table 3). The same condition existed with the slash lots, but to a lesser degree (table 4). Simple correlation coefficients between nursery emergence at 6 weeks and

Table 2. Laboratory germination and germination predicted by the ASA-610 for 25 lots each of loblolly and slash pines. Each value is the mean of two replications

Loblolly		Slash	
Laboratory germination	Predicted by ASA-610[a]	Laboratory germination	Predicted by ASA-610[b]
percent			
89	96	91	90
86	97	90	92
75	94	88	92
74	78	88	98
72	61	87	71
68	84	86	90
68	68	85	94
66	73	84	97
59	81	83	86
56	74	80	74
56	58	79	88
54	73	76	88
54	69	76	74
51	58	74	89
48	92	71	82
44	77	70	61
41	82	64	74
38	66	64	49
32	84	62	66
18	77	57	24
16	96	56	72
16	67	56	38
2	18	50	52
1	12	20	22
0.5	2	14	21
Mean			
47	69	70	71

a/ Partition value = 70.
b/ Partition value = 80.

mean conductivity of seed leachates was -0.6390 for loblolly and -0.6576 for slash (both significant at the 5 percent level). Correlation coefficients between laboratory germination and mean conductivity were also significant: -0.8197 for loblolly and -0.8497 for slash. The higher coefficients for laboratory germination were not surprising, as additional environmental factors which can inhibit germination abound in nursery beds.

Table 3.--Laboratory germination, germination predicted by the ASA-610, and nursery emergence at 6 weeks for 25 lots of loblolly pine.

Loblolly		
Laboratory germination	Predicted by ASA-610[a]	Nursery emergence @ 6 weeks
percent		
96	86	57
92	85	60
88	68	60
88	84	56
88	78	57
88	40	49
85	62	46
84	86	43
80	88	59
80	88	38
79	64	48
78	82	47
75	87	56
74	73	28
74	62	45
68	76	42
67	72	46
66	42	45
63	44	32
58	68	32
56	52	13
52	73	27
49	46	22
39	55	18
1	12	1

a/ Partition value = 70.

At this stage of the work, the following conclusions seem reasonable:

(1) The principle of the method is biologically valid, and significant correlations between seed quality and leachate conductivity can be shown.

(2) With the methods of measurement used so far, variation is still large. Experiments are underway to solve this problem by studying such factors as:
   (a) soaking time - less than 48 hours may be sufficient.
   (b) amount of seed - with one seed per cell there seems to be better correlation as seed size increases (shortleaf < loblolly < white < slash < longleaf).

Table 4.--Laboratory germination, germination predicted by the ASA-610, and nursery emergence at 6 weeks for 25 lots of slash pine

Slash		
Laboratory germination	Predicted by ASA-610[a/]	Nursery emergence @ 6 weeks
	----percent----	
90	94	41
89	82	52
86	94	39
85	98	44
85	89	38
84	96	34
79	80	46
78	86	41
78	82	43
74	91	41
70	84	32
70	93	35
69	84	57
69	84	29
66	84	37
65	74	28
65	80	39
64	84	30
63	88	34
62	58	30
61	90	38
57	38	29
48	68	27
42	36	26
36	42	16

a/ Partition value = 80.

(c) cleanliness of seed - dirty seed lots give more variation - a standard preliminary wash may help.
(d) agitation during leaching - this could easily be standardized and perhaps cut down on test time.
(e) temperature during leaching - higher temperatures might speed the measurement time.
(f) pretreatments - stratification or chemical treatments should be studied.

(3) Leachate conductivity measurements will probably never match the precision of germination tests, but there is a great deal of interest in a reliable measure of seed quality that can give results within 24 hours without the subjectivity of X-ray or tetrazolium tests.

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