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Sowing Rates for Reforestation By the Seed-spotting Method

GILBERT H. SCHUBERT AND HARRY A. FOWELLS

ABSTRACT: Presents guides to determine the number of seeds to sow per spot and the number of spots required per acre to obtain acceptable stocking. Based on theoretical probabilities, these guides were found to be reasonably close to actual field results when the probability-of-success was at least 55 percent. To compensate for lower actual stocking, increase the number of spots per acre rather than sow more seeds per spot.

In reforestation by the seed-spotting method, errors in judging the number of seed to be sown per spot may result in silvicultural problems. If too few seeds are sown, a number of spots may have no seedlings. If too many are sown, some spots may require thinning.

This note suggests a procedure for estimating rates of sowing for desired stocking.

Various sowing rates have been used in the past. In the earlier studies in California, 10 to 20 seeds were sown per spot (Dunning 1940) or enough seed to insure that at least one seed germinated per spot (Keyes and Smith 1943). In more recent studies, this rate was reduced to 5 to 10 seeds per spot (Fowells and Schubert 1951; Roy 1957; Roy 1961). Corson and Fowells (1952) recommended that five seeds be sown per spot, based on the assumption that ordinarily the chances were about 1 in 4 that a seed will germinate and the seedling live. Roy (1957) suggested that 5 seeds should be sown per spot if the viability was 50 percent or more and up to 29 seeds for 10 percent viability.

Sowing rates have varied even more in other regions of the United States. In one of the first published reports on direct seeding, Cox (1911) indicated that about 12 viable seeds should be sown per spot. In the Southwest, Pearson (1950) recommended sowing 10 to 15 seeds per spot, and Krauch (1936, 1938) sowed from 30 to 40. But in Oregon, Stein (1957) recommended sowing only two good seeds per spot and doubling the number of spots.

Numerous problems are encountered in any attempt to determine precisely the number of seeds to sow per spot to obtain adequate stocking. The most serious problem is that the factors affecting seed germination and seedling survival may not occur at

random. For example, rodents or insects may destroy one or all seeds or seedlings in a spot. Furthermore, if one seed or seedling is destroyed, the chances of the other seeds or seedlings escaping destruction are reduced. These obstacles may seem to prevent any mathematical approach to the determination of sowing rates. Effective rodent control and insecticides, however, should minimize these nonrandom effects.

Factors of climate and soil also affect seed germination and seedling survival. The nonrandom effects of these factors, however, can be minimized--but not eliminated entirely--by careful location of the seedspot to avoid unfavorable microclimatic and microedaphic conditions.

Several investigators have furnished guidelines on sowing rates. For example, Roy (1957) suggested rates based on seed viability. Wagg (1958) also used a sowing rate in Oregon that was related to seed viability. Lavender (1954) sowed 2 to 20 seeds per spot, and found that the number of seedlings under wire screens varied almost directly with the number of seeds sown and that survival was about the same for all sowing rates. Stein (1957) doubled the spots per acre to improve stocking and distribution. However, none of the investigators have adjusted the sowing rates for each spot to reflect expected survival.

Theoretical Basis for Sowing Rates

The number of seeds to be sown per spot can be set theoretically on the basis of probability. The probability or chance that a seed will germinate and the seedling will survive can be expressed as a product of (a) the germination percent, and (b) the survival percent. If this chance is designated by "P", then the chance that either the seed germinates and the seedling dies or that the seed does not germinate is $100-P$, or Q. The product of the germination percent and the survival percent has been designated as the "probability-of-success."

The germination percent in the field will probably be less than the indicated viability of a seed lot as determined by a laboratory germination test. If data are available, the field germination percent should be used to determine the probability-of-success. If only the laboratory viability is known, the planter should recognize that he is probably over-estimating germination.

The survival percent must be based on the best estimate for seedling survival for the particular area to be seeded. It should be based on the total number of seedlings and not on a stocked seedspot basis. An average survival for several years will smooth out some of the variation caused by place and time. In the absence of such data, the planter might select a survival percentage between 25 and 50--depending on the severity of the sites.

The probability of obtaining one or more seedlings per spot can be estimated by expansion of the binomial $(P + Q)^n$, in which "P" equals the probability-of-success, "Q" the probability of failure (or $100-P$), and "n" equals the number of seeds sown per spot. Figure 1 illustrates for values of "P" up to 80 percent and values of "n" up to 10 seeds, the percentages of spots having 1 or more seedlings per spot. For example, if the seed viability is 80 percent and 30 percent of the seedlings survive, to give a probability-of-success of 24 percent, 42 percent of the spots would have 1 or more seedlings if 2 seeds are sown per spot. If 5 seeds were sown per spot, 74 percent would have 1 or more seedlings. For a probability-of-success of 50 percent, 75 percent of the spots would have 1 or more seedlings when 2 seeds are sown per spot and 97 percent when 5 seeds are sown.

Comparison of Actual and Expected Stocking

Direct seeding trials by the Pacific Southwest Station have resulted in reasonably close agreement between actual stocking and the theoretical expectations based on known viability and survival when the probability-of-success was high (table 1). When the probability-of-success was 55 percent or more, the actual stocking was only 1 to 10 percent less than the expected stocking. The actual stocking was often much lower than expected when the estimated probability of success was less than 50 percent.

How to Determine Sowing Rates

The curves for expected stocking (fig. 2) give the number of seeds to sow per spot to obtain a desired stocking in terms of percent of seed spots having one or more seedlings per spot in relation to seed spots sown. For example, if the probability-of-success is 40 percent, 6 seeds would be required for a desired stocking of 95 percent. But only 3 seeds are required per spot for a stocking of 80 percent. To obtain a stocking greater than 95 percent will generally require more seeds per spot than would be warranted by the small increase in expected stocking. Since these stocking level curves are based on the number of seeds sown per spot for each probability-of-success, the planter can use these curves as a guide to conserve and to make more efficient use of seeds.

Importance of Seed Quality

Seed quality affects both seed germination and seedling survival. The importance of seed quality is quite apparent in (fig. 2). For example, at the 95 percent stocking level only 2 seeds are required for seeds with a viability of 80 percent if all seedlings survive. At 40 percent for viability, 6 seeds would be required; at 15 percent it would take 19 seeds. Since survival is rarely 100 percent, even more seeds are required than indicated in the examples.

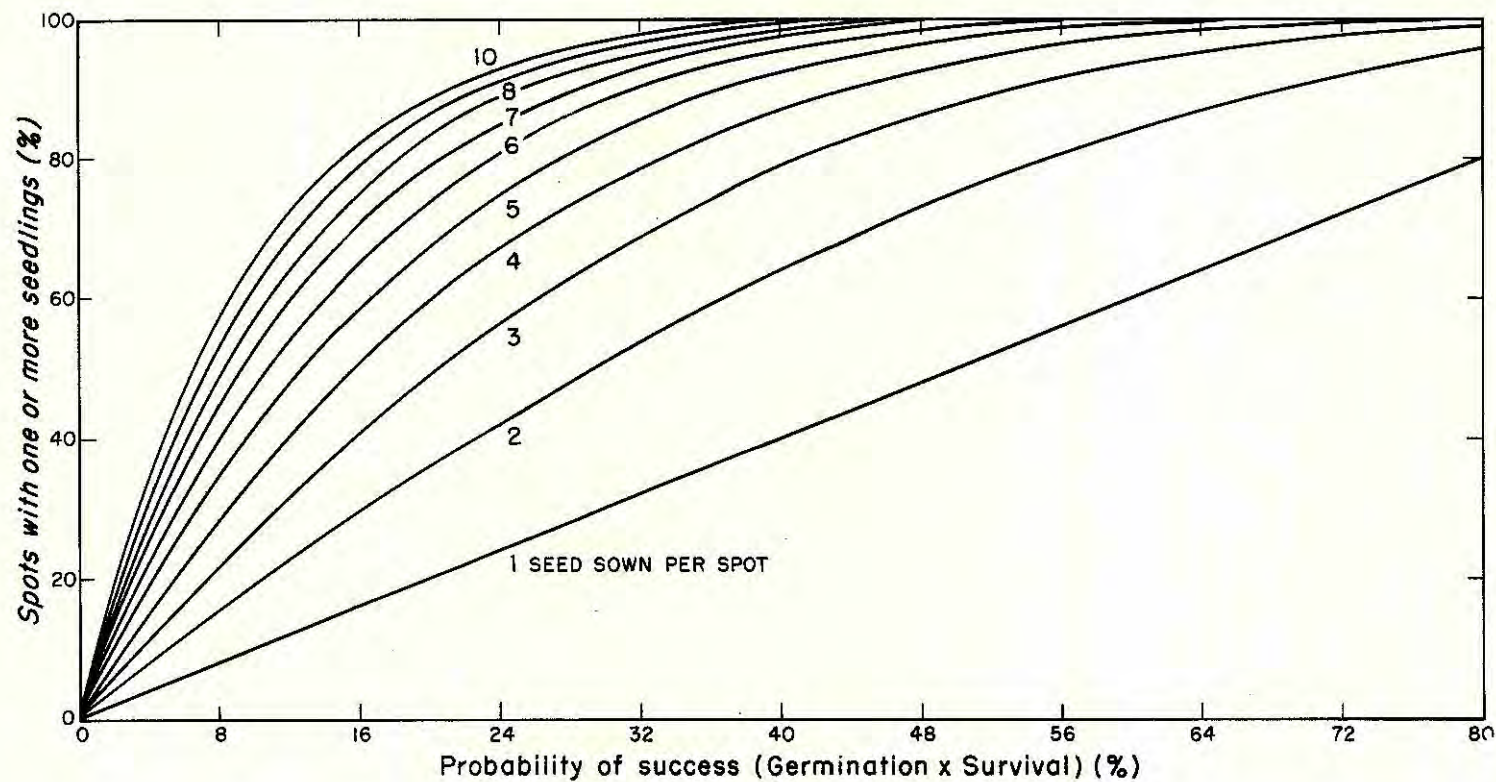


Figure 1. --Expected proportion of seedspots having one or more seedlings per spot, for various probabilities of success when 1 to 10 seeds are sown per spot.

Table 1. Comparison of actual and expected seedspot stocking¹

Species	Seeds sown per spot	Seed spot basis	Probability of success ²	Seed spots with one or more seedlings	
				Actual	Expected ²
	Number	Number	Percent	Percent	Percent
Douglas-fir	10	270	31	71	97
Jeffrey pine	5	160	72	99	100
Jeffrey pine	5	1,750	55	88	98
Jeffrey pine	5	500	32	65	86
Jeffrey pine	10	950	55	94	100
Ponderosa pine	5	160	56	92	99
Ponderosa pine	5	2,582	50	85	97
Ponderosa pine	5	200	41	73	93
Ponderosa pine	5	100	28	56	80
Ponderosa pine	5	100	49	69	97
Ponderosa pine	5	832	50	80	97
Ponderosa pine	7	500	15	49	68
Ponderosa pine	10	2,700	50	85	100
Sugar pine	5	600	24	45	74
Sugar pine	5	200	12	39	47
Sugar pine	5	160	36	74	89
Sugar pine	5	430	54	87	98
Sugar pine	5	352	46	68	90
Sugar pine	5	162	36	59	89
Sugar pine	5	946	40	76	92

¹Data from seed spots protected against rodent depredation where specific numbers of seeds were sown per spot and germination and survival was on a seed and seedling basis.

²Based on known viability and survival.

Table 2. Number of seed spots to sow per acre for several stocking levels and expected stocking rates

Expected stocking (percent)	Desired stocking levels per acre--							
	400		600		800		1,000	
	Spots needed	Spacing	Spots needed	Spacing	Spots needed	Spacing	Spots needed	Spacing
	Number	Feet	Number	Feet	Number	Feet	Number	Feet
10	4,000	3.3	6,000	2.7	8,000	2.3	10,000	2.1
20	2,000	4.7	3,000	3.8	4,000	3.3	5,000	3.0
30	1,330	5.7	2,000	4.7	2,670	4.0	3,330	3.7
40	1,000	6.6	1,500	5.4	2,000	4.7	2,500	4.2
50	800	7.4	1,200	6.0	1,600	5.2	2,000	4.7
60	670	8.1	1,000	6.6	1,330	5.7	1,670	5.1
70	570	8.6	860	7.1	1,140	6.2	1,430	5.6
80	500	9.3	750	7.6	1,000	6.6	1,250	5.9
90	440	9.9	670	8.1	890	7.0	1,110	6.2
100	400	10.4	600	8.5	800	7.4	1,000	6.6

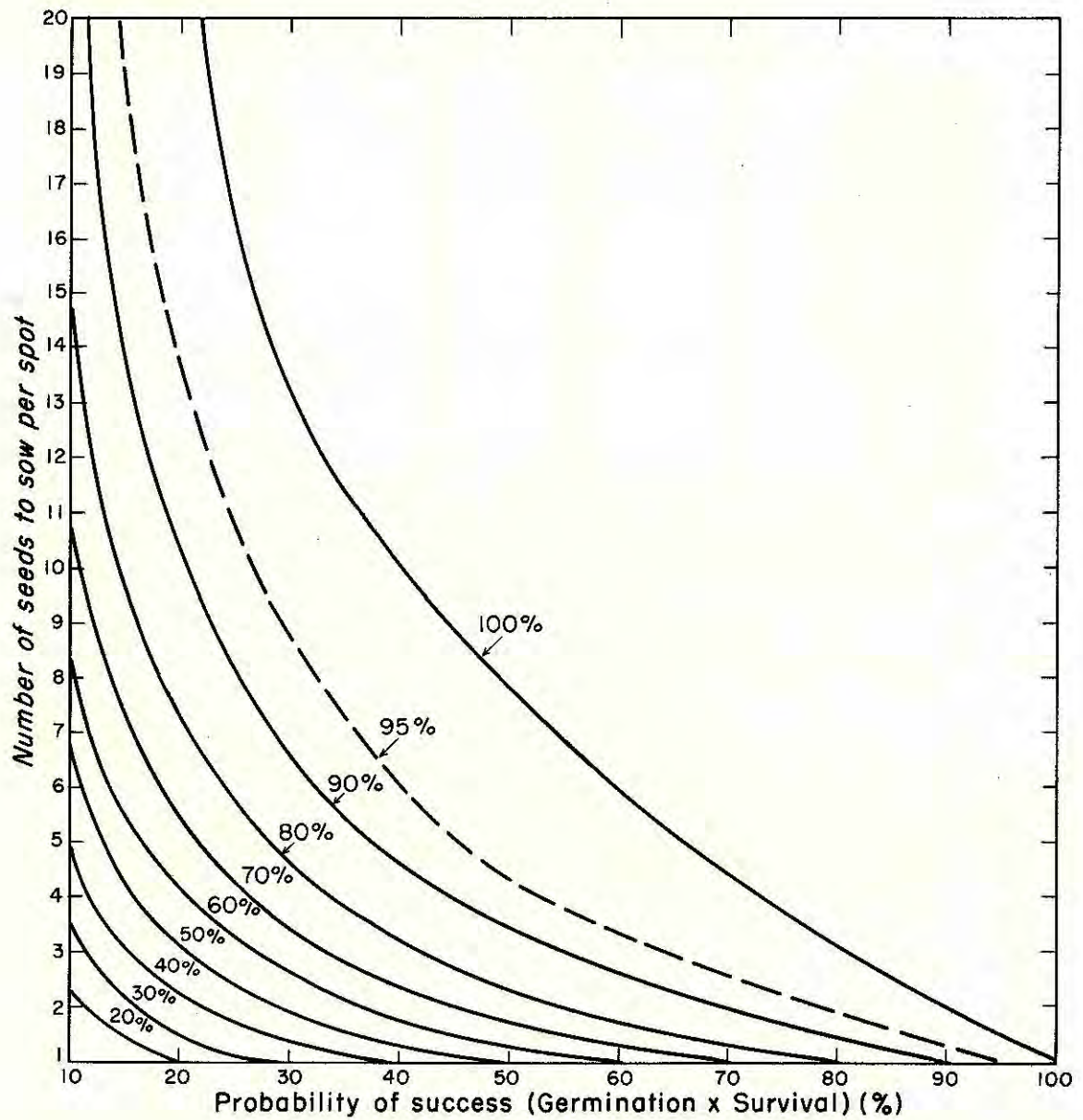


Figure 2. --Expected stocking curves (percent of seedspots with one or more seedlings) for various probabilities of success and sowing rates.

Number of Seedspots Per Acre

The curves in (fig. 2) provide a guide for estimating the number of seedspots to be planted per acre to achieve a given stocking. For example, the 90 percent stocking curve indicates all the combinations of probabilities-of-success from 10 to 90 percent and the numbers of seeds sown per spot from 1 to 20 that will result in about 900 stocked spots out of 1,000 sown per acre. If 800 stocked spots are required, 889 spots would have to be planted (800 divided by 90 times 100). The number of seedspots to sow per acre to obtain a desired stocking has been computed for several stocking levels and expected stocking probabilities (table 2).

Conclusion

The procedure for estimating sowing rates depends upon randomness of events and on good estimates of germination and expected survival. Obviously, these conditions will seldom be completely satisfied. But the experienced planter should know about what the germination of his seed is and should be able to estimate what the survival might be. With such estimates, the planter can use the curves and tables in this note to guide his planting rates. To be on the conservative side, he should plant more spots per acre rather than more seeds per spots and thereby run the risk of having overstocked spots.

Literature Cited

- Corson, C. W., and Fowells, H. A.
1952. Here's how--a guide to tree planting in the California pine region. U. S. Forest Serv. Calif. Forest & Range Expt. Sta. Misc. Paper 8, 26 pp., illus.
- Cox, William T.
1911. Reforestation on the national forests. U. S. Dept. Agr. Forest Serv. Bul. 98, 57 pp., illus.
- Dunning, Duncan.
1940. Direct seeding experiments in California. In, Experimental direct seeding by the Forest Service, pp. 18-24. (By M. A. Huberman) Washington, D. C.
- Fowells, H. A., and Schubert, G. H.
1951. Recent direct seeding trials in the pine region. U. S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 78, 9 pp.
- Keyes, Joseph, and Smith, Clarence F.
1943. Pine seed-spot protection with screens in California. Jour. Forestry 41: 259-264, illus.
- Krauch, Hermann.
1936. Some factors influencing Douglas-fir reproduction in the Southwest. Jour. Forestry 34: 601-608.
1938. Use of protective screens in seed-spot sowing found to serve two-fold purpose. Jour. Forestry 36: 1240.
- Lavender, Denis P.
1954. A preliminary report on the Douglas-fir spot seeding experiment. Oregon State Board Forestry Res. Note 15, 4 pp., illus.
- Pearson, G. A.
1950. Management of ponderosa pine in the Southwest. U. S. Dept. Agr., Forest Serv. Agr. Monog. 6, 218 pp., illus.
- Roy, D. F.
1957. Forest tree planting--here's how in the Redwood-Douglas-fir region of California. U. S. Forest Serv. Calif. Forest & Range Expt. Sta. Misc. Paper 20, 31 pp., illus.
1957. Seed spot tests with tetramine-treated seed in northern California. Jour. Forestry 55: 442-445, illus.
1961. Seed spotting with endrin-treated Douglas-fir seed in northwestern California. U. S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Tech. Paper 61, 12 pp., illus.

Stein, William I.

1957. A successful direct seeding of sugar pine. U. S. Forest Serv. Pacific NW. Forest & Range Expt. Sta. Res. Paper 25, 19 pp., illus.

Wagg, J. W. Bruce.

1958. Spot seeding ponderosa and Jeffrey pine. Oregon Forest Lands Res. Center Res. Note 35, 19 pp., illus.

GILBERT H. SCHUBERT and HARRY A. FOWELLS were formerly on the research staff of the Pacific Southwest Forest and Range Experiment Station. Gilbert H. Schubert is now with the Rocky Mountain Forest and Range Experiment Station, Flagstaff, Arizona, and Harry A. Fowells is with the Division of Timber Management Research, U. S. Forest Service, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
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BERKELEY, CALIFORNIA 94701
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