Effect of Seed Coating on Performance of Lettuce Seeds in Greenhouse Soil Tests[1]

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Abstract. Performance of raw seeds of 2 lettuce, *Lactuca sativa* L., cultivars was compared with that of seeds from the same lots that had received 7 different seed coatings. Total emergence and coefficient of variability of plant weights at 20 days were equal for coated and raw seeds in most instances. Coated seeds emerged 1 to 2 days later than raw seed and resulted in lower seedling weights. Seed coatings make possible precision planting of lettuce with apparently no sacrifice in overall performance.

There is renewed interest in the use of coated seeds to aid in complete mechanization of vegetable production and to simplify greenhouse and home garden operations. The term coated refers to a seed that has been pelleted, tableted, or taped.

Potential advantages of seed coating are: a) precision planting and spacing of small, irregularly shaped seeds; b) reduced thinning costs; c) reduced thinning shock; d) more uniform seed microenvironment; e) inclusion of beneficial chemicals with the seed; and f) use of fewer seeds.

The idea of coating seeds is not new. Burgessor (8) reported that the first patent relating to seed coating was issued in 1868. However, not until the 1940's did a real interest develop in the commercial application of seed coating.

Vogelsang (24, 25, 26) was one of the first advocates of seed pelleting. He widely acclaimed the potential benefits of his process and formed a company to commercially produce pelleted seeds. Now, many companies are producing coated seed products or developing seedcoating techniques. A survey by Asgrow Seed Company revealed that in 1974 some 43% of the nation's vegetable growers used precision planting techniques with coated seed being a key factor in the success of these techniques (2).

The 3 basic coating systems are pellets, tablets, and tape. Burgessor (8) differentiated between pellets and coated seeds as follows: "The term 'coated seed' refers to a single seed coated with an inert material, primarily to increase its size to facilitate planting. Pelleted seeds are a mixture of seed and an inert material formed into pellets, usually by molding by some mechanical means. The number of seeds in a pellet is not controlled accurately. . . ." Pellets as defined by Burgessor are not being produced, however, the term "pelleted" is often used to describe coated seeds which result from the layering of a substance on the seed through a process of accretion.

A seed tablet, also called "wafer", is much larger than a coated seed (1.5 – 2.0 cm diam.) but still contains only a single seed. A tablet may consist of 2 halves of a tablet glued together or a single unit with the seed embedded in the middle. Whereas a pelleted seed is produced by accretion, a tablet results from compression of the material (usually vermiculite or charcoal) to form the tablet.

The third process of coating involves the manufacture of "seed tape" which is a water-soluble plastic tape or a strip of paper with seeds located at specific intervals. Seeds are evenly spaced on the tape, which may then be folded over the seeds and bonded. When the tape is planted, the seeds are automatically spaced at the desired intervals.

To our knowledge, a thorough review of the literature on seed coating has not been published. Because products have changed over the years and continue to change rapidly, much of the literature is of only historical interest. Listed below are some key references, grouped by specific application. Other citations may be found in them: a) reseeding range and forest land (3, 5, 9, 14); b) aid to legume inoculation (6, 7, 13, 21, 23, 27); c) precision planting (4, 10, 11, 12, 16, 17, 18, 20, 22, 29, 30).

Our objective was to answer 2 questions: a) how do coated seeds perform relative to raw seeds? b) What parameters are useful for comparison of coated seeds with raw seeds? It was not our objective to compare the various proprietary products; therefore, the coating treatments were coded. Seed-coating technology is still being developed and since our study was conducted some of the products have been discontinued or radically changed. Lettuce seed was chosen for the experiment because lettuce requires precise spacing for optimum plant development. Also, lettuce is being studied intensely for complete mechanized production.

Materials and Methods

Seeds of 2 lettuce cvs., Ithaca and Mesa 659, were received in March 1972. The seeds had an initial germination of 99.5 and 98.0%, respectively. About 0.5 kg of seed from each cultivar was sent to each of the following companies for coating: Asgrow Seed Co.; Union Carbide Corporation, Creative Agricultural Systems; Ferry-Morse Seed Co.; FMC Corporation, Niagara Chemical Division; Germain's, Inc.; Moran Seed Co.; and Royal Sluis Co., Holland. The coated seeds were returned between April and June 1972, and our experiment was started the next December.

The initial germination values were based on the standard Association of Official Seed Analysts germination test (1), with 2 replications of 100 raw seeds from each treatment. To obtain raw seeds we rinsed the coated seeds in tap water long enough to remove the coating material (approx. 1-2 min.).

The seeds were planted at 2 depths, 0.6 cm and 1.9 cm, in greenhouse flats in 2 screened (0.64 cm) virgin soils, a clay loam and a loamy sand. The chemical and physical properties for each soil are summarized in Table 1. The seeds were placed on top of the dry soil and forced into the soil to the desired depths with measured bolts. Tablets were planted on edge so as to place the seed at the desired depth.

All seeds were hand-planted in replications of 12 seeds per plastic container (17.0 x 12.5 x 5.5 cm) with 12 replications on 4 greenhouse benches. The diurnal temperature fluctuations, monitored by a thermocouple recorder were 12.6 to 25.0°C for air and 8.8 to 18.8°C for soil (mean daily minimum to mean daily maximum).

After all the seeds had been planted, the containers were watered to field capacity for each soil type. Soil moisture was monitored by weighing selected containers daily. Moisture content was kept be-

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[5] Mention of a trademark name or a proprietary product does not constitute a guarantee or warranty of the product by the USDA or Colorado State University and does not imply its approval to the exclusion of other products that may also be suitable.

tween 16 and 29% for the clay loam and between 6 and 12% for the loamy sand. Three times during the 20-day period a nutrient solution containing 46 ppm N, 16 ppm P, and 70 ppm K was used to water the containers.

Parameters measured were total emergence; velocity of emergence; seedling wt; and plant-to-plant variability in seedling wt.

Emerged seedlings were counted daily between 8 and 9 a.m. for 20 days, at which time seedlings were weighed. Each seedling from 5 of the replications was weighed to the nearest 0.2 mg. Each of the remaining replications was also harvested, and seedlings from each container were bulk-weighed to the nearest 10 mg.

The experiment was a randomized complete block, designed as an 8 (coating) x 2 (cultivar) x 2 (soil) x 2 (depth) factorial with 12 replications. Percentage of emergence and coefficients of varibility (CV) were analyzed after arc-sine transformation. Nontransformed means are presented in the tables for clarity. For the cultivar analysis we used the 5 replications in which individual seedlings were weighed. Coefficients of velocity of emergence were calculated by the formula developed by Kotowski (15):

$$\text{Coefficient of velocity} = 100\,\frac{A_1 + A_2 + \cdots + A_x}{A_1T_1 + A_2T_2 + \cdots + A_xT_x}$$

A = Percentage of seedlings emerged each day.
T = Number of days after planting corresponding to A.

Percentage of emergence per day was based on the 12 replications of 12 seeds (i.e., 144 seeds). In calculation of the denominator of the Kotowski equation, day "4" after planting (the first day any seedlings were observed) was taken as day "1."

Table 1. Chemical and physical properties of experimental soils.

Parameter measured	Clay loam	Loamy sand
NO_3-N (ppm)	4.0	1.8
P (ppm)*	1.3	11.7
K (ppm)*	190	223
Zn (ppm)*	0.78	0.32
Fe (ppm)*	10.9	4.6
pH	6.5	7.3
Lime (%)	1–2	1–2
Conductivity (mmhos/cm)	0.31	0.46
Organic matter (%)	1.3	0.6
Particle size (%)		
Sand	38.4	80.2
Silt	26.7	11.2
Clay	34.9	8.6
Moisture at 1/3 atm (%)	26.5	7.7

* Extracting solutions: P = $NaHCO_3$, K = $NH_4C_2H_3O_2$, Zn and Fe = DPTA + TEA

Table 2. Missing seeds, doubles, and germination in the laboratory of coated lettuce seeds of 2 cvs. (M, Mesa 659 and I, Ithaca).

Coating	No. missing seeds (%)		No. doubles (%)		Germination[z] (%)	
	M	I	M	I	M	I
A	7.3	2.7	0	0	88	99
B	0.7	0	1.3	0.7	97	100
C	6.4	2.7	0	0	97	100
D	0.7	0	8.0	8.0	59	94
E	0	3.3	0	0	97	99
F	0.7	1.3	1.3	0.7	98	98
J	1.3	2.0	0	0.7	99	99
Control	—	—	—	—	98	99

[z] Seeds were removed from the coating material before germination. Seeds tested in January 1973.

Results

Except for treatments 'Mesa 659' coatings A and D, all of the seeds germinated 94% or better (Table 2), indicating good seed quality at the start of the experiment. The number of missing seeds, doubles, or both was very low, an important quality for precision planting. Coating samples which contained 6 to 8 percent missing or doubles would be of some concern to a grower wishing to eliminate the thinning operation.

Emergence after 20 days was only slightly affected (although statistically significant) by soil type and depth of planting (Table 3). The same can be said for coefficient of variability. Seedling wt, on the other hand, was greatly affected by soil type and planting depth. Both

Table 3. Main effects of cultivar, soil type, and depth of planting on lettuce seed performance.

Cultivar	Emergence (20-days) (%)	Seedling wt (mg)	Coefficient of velocity of emergence	Coefficient of variability (%)
Mesa 659				
Soil type				
Clay	85	29	18	29
Sand	82**	50**	17	35**
Depth of planting				
0.6 cm	85	46	23	29
1.9 cm	82**	33**	13**	35**
Ithaca				
Soil type				
Clay	91	42	21	28
Sand	89	74**	20	35**
Depth of planting				
0.6 cm	92	68	27	29
1.9 cm	88**	47**	14**	33

** Mean pairs within a column differ very significantly (1% level).

Table 4. Lettuce emergence (% seeds planted) after 20 days (M = Mesa 659; I = Ithaca).

Coating	Soil: Clay		Soil: Sand		Depth: 0.6 cm		Depth: 1.9 cm		Overall	
	M	I	M	I	M	I	M	I	M	I
A	(9)[z]	(73)[z]	(4)[z]	(50)[z]	(12)[z]	(80)[z]	(0.7)[z]	(43)[z]	(6)[z]	(62)[z]
B	95	92	93	91	97	93	91	90	94	92
C	88	89	80**	91	85	91	82	89	84	90
D	40**	89	44**	89	44**	92	41**	86	42**	89
E	93	94	80	91	93	94	90	91	91	92
F	91	93	85	90	89	92	87	91	88	92
J	91	89	81**	84**	88	88	84	85	86	86**
Control	89	90	92	92	91	93	90	90	91	91

[z] Means were ommitted from analysis.
** Mean within a column differs very significantly from the control mean (1% level).

clay soil and 1.9-cm planting depth reduced seedling wt. Coefficient of velocity of emergence was affected only by depth of planting, being much lower at the 1.9-cm depth.

Total emergence was generally not affected by coating the seeds (Table 4).

Seedling wt at 20 days from coated seed was lower than that of the control in most treatments (Table 5).

Coating the seeds did tend to slow emergence. The coefficient of velocity of emergence includes both total emergence and speed of emergence. Therefore, differences in coefficient of velocity of emergence were caused mainly by speed of emergence. Analysis of variance showed that soil type did not influence rate of emergence (Table 3). In the depth x coating interaction (Table 6), at the 0.6-cm depth, the control outperformed all coatings. At 1.9-cm planting depth, only treatment A was poorer than the control.

We plotted the percentage of seeds emerging each day vs. days from planting for treatment B and the control (Fig. 1). At the 0.6-cm planting depth, emergence of the coated seeds lagged 2 days after that of the control. At the 1.9-cm depth, the emergence patterns were almost identical for coated and raw seeds.

Finally, the uniformity of coated vs. raw seeds was compared. Coefficients of variability were calculated, based on the 20-day seedling wt. Coating x soil type or planting depth had no interaction. Only 3 treatments, 'Mesa 659' coating D and 'Ithaca' coatings A and C, had significantly higher coefficients of variability than their respective controls (Table 7).

Table 5. Lettuce seedling wt (mg) after 20 days (M = 'Mesa 659); I = 'Ithaca').

Coating	Soil				Depth				Overall	
	Clay		Sand		0.6 cm		1.9 cm			
	M	I	M	I	M	I	M	I	M	I
A	(6)^z	(28)^z	(3)^z	(20)^z	(7)^z	(29)^z	(2)^z	(18)^z	(5)^z	(24)^z
B	31	46	58	78	51	73	37	51	44	62
C	30	37	40**	34**	40**	41**	30**	30	35**	36**
D	21**	45	34**	91	30**	78	24**	58	27**	68
E	30	43	47**	79	45	72	31**	50	38**	61
F	31	42	48**	76	46	69	33	48	39**	59
J	31	40	56	74**	50	66**	37	48	43	57**
Control	31	43	59	85	51	78	39	50	45	64

^{z} Means were omitted from analysis.
** Mean within a column differs very significantly from the control mean (1% level).

Table 6. Coefficients of velocity of emergence for lettuce seeds (M = 'Mesa 659'; I = 'Ithaca').

Coating	Planting Depth				Overall	
	0.6 cm		1.9 cm		0.6 cm	1.9 cm
	M	I	M	I		
A	(8)^z	(13)^z	(4)^z	(10)^z	(11)^z	(7)^z
B	25	28**	15	16	27**	16
C	19**	13**	13	10	16**	11
D	13**	34	10	17	24**	13
E	23**	30**	13	16	27**	15
F	24**	25**	14	14	24**	14
J	27	30	15	15	29**	15
Control	33	38	17	15	36	16

^{z} Means were omitted from analysis.
** Mean within a column differs very significantly from the control mean (1% level).

Table 7. Coefficients of variability for lettuce seedling wt.

Coating	Cultivar	
	Mesa	Ithaca
A	—	40**
B	30	26
C	35	42**
D	61**	27
E	33	26
F	27	30
J	30	30
Control	30	29

** Mean within a column differs very significantly from the control mean (1% level).

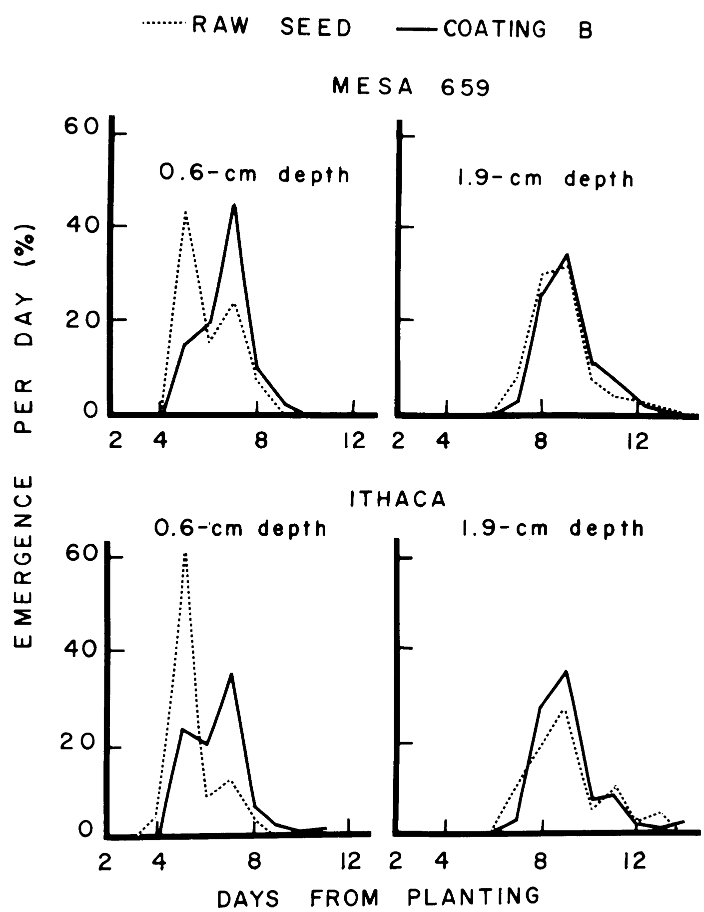

Fig. 1. Emergence rate of coated vs raw lettuce seeds.

Discussion

Most companies required a minimum of 250 g of raw seed for coating the seeds effectively. Although high-quality seed were used, this is still a rather small quantity, compared with what might be processed for a commercial sale. The small quantity may have affected the performance of some coatings. From the germination test on the seeds removed from the coating material we saw that some treatments ('Mesa 659' coatings A and D) had significantly declined in germination capability by the time our experiment was started. They deteriorated most likely during or shortly after the coating process. Several months had elapsed between the time that the coated seeds were received and the time that the data were acquired for Table 2. However, the materials were stored under excellent conditions (5°C, 40% relative humidity) during that period. If the coating process caused the deterioration, it was probably a matter of quality control with the small size. This problem can be solved, because the other cultivar ('Ithaca' coatings A and D) did not have this problem. We believe that deterioration was not a cultivar effect. It is possible that deterioration occurred during storage particularly if the moisture content was high in the coating material. We are currently conducting storage experiments on coated seed.

A 1.9-cm planting depth was used to apply a stress to the germinating seeds. Zahara (28) had shown that a 1.9-cm planting depth significantly slowed emergence and reduced total emergence of lettuce seeds. Our data confirmed this reduction.

The 2 soils were chosen to provide a greater diversity in environment and to allow for greater expression of variability. Soil type affected seedling wt most. Part of this soil effect might be ascribed to nutritional factors (Table 1), since emergence was affected only slightly. The P level was much lower in the clay loam than in the loamy sand and may have caused the seedling wt to be lower in the clay loam.

Of some concern to manufacturers of coated seeds are the water-holding properties of various soils. Although we did not specifically study the absorption properties of the coating materials, the soils provided 2 levels of water-holding capacity. As pointed out by Millier and Bensin (19), coated seeds perform differently, depending on the hydrophillic or hydrophobic properties of the coating material and the soil-water content. These factors should be considered by manufacturers and users of coated seeds.

Of the 4 performance parameters considered in this experiment, total emergence seemed to be the least useful in evaluation of coated lettuce seeds. A standard laboratory germination test on seeds removed from the coating material gave about the same information as the soil test. On the other hand, coefficient of velocity of emergence was much more useful in identifying a common trait of most coated seeds: that is, they emerged slower than raw seeds, but only when seeds were planted 0.6 cm deep. Most of the differences in seedling weight of coated and raw seeds could be attributed to the slower emergence of the coated seeds. The failure to find many instances in which plant-to-plant variability increased upon coating the seeds is most encouraging for complete mechanization of lettuce production.

The use of coated seeds has some problems yet to be solved: better quality control in the coating procedure; composition of the coating material for specific soil conditions; development of specialized planters; handling and storage of coated seeds; and development of standardized laboratory germination procedures for coated seed.

In summary, with respect to total emergence, only coating A failed to perform as well as the raw seeds. With respect to seedling wt, both coatings A and C were inferior to raw seeds. With other coatings, that at least 1 of the cultivars would match the control indicates the efficacy for seed coating processes. Although the coefficient of velocity of emergence was generally lower for coated seeds than for raw seeds at the 0.6-cm planting depth, seedling wt did not decrease correspondingly. Nor did the coefficient of variability increase for these wt. The performance of coating seeds never exceeded that of the raw seeds.

In evaluating the 4 parameters, we found that neither total emergence nor coefficient of variability adequately described the performance of coated seeds. However, both coefficient of velocity of emergence and seedling wt at 20 days revealed numerous differences between coated and raw seeds. Correlations between these 2 factors for either cultivar in either soil ranged for $R = 0.91$ to 0.99 (quadratic relationships), indicating that those factors were probably measuring the same thing. More studies are needed to determine which parameter best predicts actual field performance.

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