SEGMENTED SUGAR-BEET SEED WITH SPECIAL REFERENCE TO NORMAL AND ABNORMAL GERMINATION [1/]

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Introduction

Single-germed sugar-beet seed has long been sought by individuals connected with the sugar-beet industry. Attempts to produce seed with only a single germ by the process of selection have made very little progress. Townsend and Rittue (6) report the early efforts of workers in the United States Department of Agriculture along this line.[3/] Bordonos (2), a Russian worker, reports that a single-germed beet seed has recently been developed by hybridizing with natural single-seeded types. However, there is no immediate prospect of single-germed seed being available to the commercial industry in this country.

Parallel with efforts to select single-germed seed, attempts have been made to "crack" the sugar-beet seedball into its component units. Palmer (3) reports that prior to 1900 some "cracked" seed from Germany was placed on the American market, but it did not give satisfactory results, and he proceeds to enumerate the difficulties encountered in the use of "cracked" seed, several of which were: 1, Some of the germs were destroyed in the cracking machine; 2, other germs were exposed and the function of the seedball to regulate germination was destroyed; 3, it was impossible to crack the seedballs without ruining a large portion of the germs, unless many pieces were left with more than one germ, in which case the field had to be thinned as usual.

Tabentsky (5) reports the efforts of some Russian workers to break single-germed seeds out of the multiple-germed seedball. He states that the structure of some seedballs was such that they broke up rather easily while some others were so completely unified by sclerenchymatous tissue that attempts to break them into units were largely unsuccessful.

Recently in the United States there has been a revival of interest in segmenting the seedball into single-seeded units, and Bainer (1) has developed machinery to do this on a commercial scale. During the past 2 years the use of segmented seed has spread rapidly due to the labor-saving possibilities it offers, and its promise to become an important factor in the ultimate

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3/ Figures in parentheses refer to Literature cited.

mechanization of the sugar-beet industry. Because of the widespread use of segmented seed it becomes important to have a fundamental understanding of functions of the pericarp tissue of the seedball and what can and cannot be done with it without seriously interfering with those essential functions.

The present report gives the results of blotter and soil tests with the seed units recovered from segmented seed as compared with the germination of whole seedballs and with naked seeds removed from the locule of the seedball.

Materials and Methods

These studies have dealt principally with three kinds of sheared seed units: 1, Perfect segmented seed (seed units with one germ completely enclosed within the seedball locule); 2, imperfect segmented seed (sheared seed in which the locule has been broken and the true seed exposed) and 3, naked seeds (seeds completely freed from the nut-like seedball locule). Segmented seed units with more than one germ have been avoided inasmuch as these do not represent conditions essentially different from normal seedballs. In all tests whole seedballs with all but one germ destroyed were used as a check to indicate normal performance.

Seeds were germinated on blotters in petri plates and in soil in specially built germinators with glass sides which permitted periodic observations to determine both hypocotyl and radicle development. Germination was carried on at room temperature in the dark except when observations were being made. The germinators were tipped at an angle so that the hypocotyls grew against the glass on one side and the radicles grew against the glass on the other.

Experimental Results

Sugar-beet seedballs vary greatly in size, weight and number of true seeds. Tests were conducted, using different seed lots to determine the effect of variety and location where the seed was produced on the average number of sprouts per seedball. The results of these tests are given in table 1. It is evident that the average number of sprouts per seedball varied from 1.35 to 2.37. Seedballs of the same variety grown in different localities and seedballs of different varieties grown in the same locality varied widely in the average number of sprouts per ball when these seedballs were germinated in soil, either in the greenhouse or in the field.

One other point is very evident. The higher the percentage germination the greater the number of sprouts per seedball. The germination percentages were higher under greenhouse conditions than from field plantings, and the average number of sprouts per ball also increased. Subsequent tests indicated that when soil moisture was varied under greenhouse conditions so as to reduce the total germination percentage, the average number of sprouts per ball was also reduced (table 2). The data in table 2 also gives a comparison of the number of sprouts per seed unit of segmented seed as compared with whole seedballs. These results add further evidence that the more favorable conditions are for germination, the greater will be the average number of sprouts per ball or seed unit.

Table 1.- Average sprouts per seedball of various lots of sugar-beet seed germinated under greenhouse and field conditions.

Variety and source of seed tested	Planted in greenhouse		Planted in field	
	Germination	Average sprouts per seed unit	Germination	Average sprouts per seed unit
	Percent	Number	Percent	Number
U.S. 22 - Port Angeles, Wn. (9301)	92	1.94	73	1.75
U.S. 15 - Klamath Falls, Ore. (9302)	70	1.42	56	1.35
U.S. 15 - Medford, Ore. (9304)	90	2.13	87	1.91
U.S. 200 - Jefferson, Ore. (9307)	97	2.37	87	2.08
U.S. 215 - Jefferson, Ore. (9308)	98	2.12	87	1.77
U.S. 33 - Ogden Valley, Utah (9309)	92	1.79	83	1.70

Table 2.- Average sprouts per germinating seed unit of segmented seed and whole seedballs planted in the greenhouse under medium and high-moisture conditions.

Kind of seed tested	12.4 percent soil moisture		16.7 percent soil moisture	
	Germination	Average sprouts per seed unit	Germination	Average sprouts per seed unit
	Percent	Number	Percent	Number
Whole seedballs	70	1.68	80	2.00
Segmented seed	61	1.24	70	1.29

Further tests were conducted to compare the actual number of sprouts developing from a unit of segmented seed as compared with the number of sprouts from whole seedballs. The results of these tests, planted in greenhouse soil are given in table 3. It is evident that inclusion of the segmented seed units ranging in size from 9/64 to 10/64 inch increased the average number of sprouts per seed unit. However, both lots of segmented seed show a striking increase in the percentage of seed units developing only one plant when compared with whole seedballs.

One factor in these tests with the segmented seed was rather disturbing. This was the fact that only 74 percent of the segmented seed units produced seedlings, whereas 92 percent of the segmented seed units germinated on blotters. In view of this fact, a rather critical examination of the segmented seed was made and it was found that it contained some naked seeds (true seeds removed from the seedball locule) also that about 25 percent of the segmented seed units with single germs had so broken in the segmenting process that the true seed was exposed. Tests were then conducted in petri dishes and in special glass germinators where the germination of the naked seeds and partially exposed seeds could be closely observed. These tests included whole seedballs with one germ, perfect segmented seed, imperfect segmented seed and three classes of naked seeds: 1, Perfect naked seeds as determined under the binoculars; 2, naked seeds with small visible cracks in the testa, and 3, naked seeds with the testa almost entirely removed. The results of these tests are given in table 4.

Table 3.- Number of seedlings per seed unit from segmented and whole seed planted in greenhouse soil.

Number of seedlings produced	Size of segmented units 1/ 7/64 to 9/64 inches	Size of segmented units 1/ 7/64 to 10/64 inches	Whole seedballs 2/
	Percent	Percent	Percent
Percentage producing 1 seedling	77	66	33
Percentage producing 2 seedlings	21	30	56
Percentage producing 3 seedlings	2	4	10
Percentage producing 4 seedlings	0	0	1
Average number sprouts per seed unit	1.25	1.38	1.78

1/ Germination percentage of segmented seed was 92 percent on blotters and 74 percent in greenhouse soil.

2/ Germination percentage of whole seed was 90 percent on blotters and 89 percent in greenhouse soil.

Table 4.- Percentages of normal and abnormal germinations of perfect segmented and perfect naked sugar-beet seeds as compared with imperfect segmented and imperfect naked sugar-beet seeds when germinated on blotters.

Kind of seed germinated	Abnormal 1/ germination	Normal 2/ germination
Perfect segmented seed	0	100
Imperfect segmented seed	60	40
Perfect naked seeds	70	30
Naked seeds with testa broken	80	20
Naked seeds with testa almost entirely broken	95	5

1/ Abnormal germination indicated by cotyledons breaking away from reserve food supply before radicle shows any signs of development.
2/ Normal germination indicated by growth of the radicle while the cotyledons remain in contact with starchy perisperm.

The data and observations indicate that there was no difference between the germination of perfect segmented seed and whole seedballs with single germs. In both cases the radicle emerged, elongated and developed root hairs, while the cotyledons remained within the locule, absorbing the reserve food supply of the perisperm. When the radicle had grown to a length of 1½ inches the cotyledons became detached from the seedball and were in position to be pushed through the soil to the surface as the hypocotyl elongated.

It was very evident, however, that many of the naked seeds and many of the imperfect segmented seeds did not germinate normally. Abnormal germination occurred in from 60 to 90 percent of the seeds in these classes. In the main this abnormality of germination consisted in the breaking away of the cotyledons from the reserve food supply almost as soon as growth started. Frequently the cotyledons opened up and the hypocotyl elongated as much as 1½ inches before the radicle showed any growth. Subsequent soil tests indicated that this loss of reserve food greatly influenced the vigor and growth habit of the young seedling.

It was also evident that both the seedball and the testa of the naked seed helped to control the progressive stages of germination.

In order to determine the effect of some of these abnormalities of germination on seedling growth in the soil, whole seedballs with one germ, perfect segmented seeds, imperfect segmented seeds and perfect naked seeds were planted in soil at depths of 1/4, 3/4, 1½, and 3 inches. The soil containers had glass sides and the seeds were planted next to the glass so that germination and growth could be observed, and the soil was firmed moderately around the seed. The results of this test are shown in table 5.

Table 5.- Comparison of the percentage of seedlings emerging when whole, segmented and naked seeds were planted at different depths in greenhouse soil.

Kind of seed planted	Emergence at various planting depths				
	1/4 inch	3/4 inch	$1\frac{1}{4}$ inches	2 inches	3 inches
	Percent	Percent	Percent	Percent	Percent
Whole seed-balls - 1 germ	92	88	87	92	90
Perfect segmented seed	90	92	88	90	88
Perfect naked seed	90	33	8	0	0
Imperfect segmented seed	85	42	25	8	13

There was good germination of the seed and 100 percent of the seedlings emerging from the perfect segmented and whole seedballs reached the surface from the deepest planting. However, only a small percentage of the seedlings from the naked seeds and imperfect segmented seeds reached the surface when the seed was planted 3/4 inch or deeper. This was thought to be due to at least three factors: 1, Reduced seedling vigor due to loss of reserve food supply; 2, mechanical difficulties due to the fact that the hypocotyl and cotyledons are not in a position to be pushed up through the soil and the radicle is not firmly anchored in the soil so that a maximum of pressure can be exerted; 3, loss of growth-controlling hormones in the reserve food supply with a subsequent loss of geotropic response. As a result of possibly the last two of these factors, the seedling becomes bent and twisted in the soil and makes little or no progress toward the soil surface.

As further evidence that seedlings from naked and imperfect segmented seeds that germinate abnormally do not have the soil penetrating power of normal seedlings, a test was run in which both depth of planting and firmness of the soil over the seed was varied. The results of this test are given in table 6.

The results of this test indicate that if it were possible to plant the seed $\frac{1}{2}$ inch or less in depth, that many of the abnormally germinating seedlings would emerge from the soil and develop into normal plants. Leaving the soil loose would also enable more seedlings to emerge. However, under field conditions, planting $\frac{1}{2}$ inch or shallower would be unsafe. Furthermore, the soil over the seed cannot be left loose without danger of excessive loss of soil moisture.

Table 6.- Comparison of the percentage of seedlings emerging when whole, segmented, and naked seeds were planted at different depths in greenhouse soil of varying compactness.

Kind of seed and firmness of seed-bed 1/	Depth of planting (inches)				
	1/16 in.	1/4 in.	1/2 inch	1 inch	2 inches
	Percent	Percent	Percent	Percent	Percent
Whole seedballs--1 germ					
Soil packed	92	90	90	80	75
Soil firm	90	82	83	85	82
Soil soft	92	92	87	88	88
Perfect segmented seed					
Soil packed	80	87	88	82	75
Soil firm	88	83	82	78	75
Soil soft	85	85	88	83	80
Perfect naked seed					
Soil packed	97	75	33	0	0
Soil firm	97	87	50	8	0
Soil soft	100	93	75	25	0
Imperfect segmented seed					
Soil packed	75	42	42	17	8
Soil firm	82	67	50	25	8
Soil soft	87	75	67	25	17

1/ Compactness of seedbed was controlled by the amount of pressure applied to the soil placed over the seeds.

Discussion

Knowledge that 20 to 25 percent of the segmented seed units have exposed seeds and that one-half or more of these will not produce a seedling when planted more than ½-inch deep offers an explanation of the discrepancy in the percentage germination of segmented seed when planted in soil as compared with the germination percentage on blotters.

The tests reported in this paper indicate that for precise results, we should know the percentage of normal germinating seed units in each lot of segmented seed planted under field conditions. Pounds of seed to plant per acre should be controlled by the percentage of seed units germinating normally and not by the total germination as indicated by blotter tests where abnormal and normal germinations have not been differentiated.

Altough the allowable variation in depth of planting is less in segmented seed than in whole seed (4), the optimum depth of planting must be the same in both cases. The optimum depth of planting for both whole seed and segmented seed is that they should be planted just as shallow as moisture will permit. Depth of planting should therefore be governed by soil moisture and not by kind of seed planted. The evidence indicates that a seedling from a perfect segmented seed will penetrate the soil just as far as will a seedling from a single-germed seedball. This does not mean, however, that single seed units, whether they be segmented or whole seedballs, will penetrate the same depth of soil or exert the same pressure against a soil crust as will three seedlings from the same seedball.

It should also be noted that there is a further grinding of the seed units in the seed drills and that there is no doubt an increase in the percentage of injured or imperfect seeds during the planting process. Improvement in drill design and in precision of manufacture will do much to eliminate this phase of the problem. However, some work should no doubt be undertaken to determine the extent of seed injury by the drill mechanism.

There is also some consideration of polishing segmented seed to make it more uniform in size. Attention should be given to the fact that any operation which tends to have a further grinding action on the seed units may injure or expose more of the true seeds and from this standpoint any such operation would be undesirable.

These studies also point out a problem in the uniform distribution of effective segmented seed units. At any given rate of seeding there will be skips where only segmented units with exposed seeds are planted. If enough seed segments are planted to insure an adequate initial stand, some bunching of plants will occur in the spaces where perfect segmented seed units fall together.

Further work with segmented seed will no doubt do much toward solving the problems which still exist. However, in these studies it would seem desirable to study further the effect of doubles in rather widely spaced beets. Data indicate that almost 90 percent of the whole seedballs in commercial seed produce not more than two seedlings. This fact should stimulate further work on the planting rate of whole sugar-beet seed to see if there is not a point where seedling distribution from whole seed plantings can not be satisfactorily worked into the mechanization program.

Summary

A comparison of the germination of segmented sugar-beet seed, whole seedballs, and naked seeds was made using blotters and soil in special glass germinators and also in the greenhouse bench. These tests showed that most naked seeds and 12 to 15 percent of the segmented seed germinated abnormally. This abnormal germination was evidenced by the fact that the cotyledons broke away from the starchy food reserve during the initial stages of germination and before the radicle had developed and

become established. The cotyledons did not remain in a position to be pushed through the soil and there was also apparent some loss in geotropic response. As a result of these abnormalities very few seedlings from naked seeds and imperfect segmented seeds emerged from the soil when planted more than ½ inch deep. It was evident that blotter germination tests gave an erroneous impression of the percentage of seed recovered in the shearing process, unless care was taken to differentiate between normal and abnormal germination.

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