Relation of Sugarbeet Germination to Maturity and Fruit Moisture at Harvest[1]

F. W. SNYDER[2]

Received for publication August 16, 1971

In the early 1960's as monogerm sugarbeet cultivars were being introduced commercially, many monogerm seedlots germinated less than commercial multigerm cultivars. Exploratory studies indicated that maturity or seed ripeness was correlated with germination performance.

The concept that seed immaturity adversely affects germination is generally accepted. TeKrony (1)[3] has reviewed the pertinent literature and reported a 3-year study on the effect of maturity on germination of sugarbeet seeds grown under field conditions in Oregon. He combined the fruits from a number of plants at each harvest to determine the average responses and relationships for an easy-bolting and a hard-bolting cultivar. Maturity, as determined by maximum germination and dry weight of the fruits, occurred at 40 to 45 days after anthesis for the specific flowers. All seeds on the plant were mature 45 days after "peak" anthesis. He indicated that all seeds should be mature when sugarbeet plants (from first anthesis) have been exposed to 900 heat units (degree days from base temperature of 45 F). Fruit color and moisture content were not reliable indicators of seed maturity. Some seeds germinated 20 days after anthesis. TeKrony concluded that underdeveloped seeds primarily caused the low germination potential.

Reported herein is the influence of seed maturity on germination in the laboratory for sugarbeet seed grown in the field in Arizona and Oregon and for seed grown in the greenhouse in Michigan. Also, germination performance has been related to fruit-moisture content at harvest, estimated commercial maturity based on fruit color, and the attainment of physiological seed maturity for individual plants. Heat unit requirements for individual plants are included.

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[1] Cooperative investigations of the Plant Science Research Division, Agricultural Research Service, U.S. Department of Agriculture, and the Michigan Agricultural Experiment Station. Approved for publication as Journal article #5606, Michigan Agricultural Experiment Station.

[2] Plant Physiologist, Plant Science Research Division, Agricultural Research Service, U.S. Department of Agriculture, East Lansing, Michigan 48823.

[3] Numbers in parentheses refer to literature cited.

Methods and Materials

Fruits were hand harvested from given plants at 4-to 6-day intervals as maturity progressed. When only a few harvests were made, the fruits were removed from similar branches on the plants.

Field-grown seed

In 1964 fruits were harvested from 13 plants of sugarbeet cultivar AI 1 × AI 2 and 10 plants of GW 823 grown near Phoenix, Arizona. The fruits were harvested at −10, −5 and 0 days, with 0 representing approximately commercial maturity on June 21. Fruits grown near Salem, Oregon in 1965 were harvested from 25 plants of cultivar (SL 126 × 129)ms × SP 6322-0 at −11, −6, and 0 days and from 25 plants of cultivar US H20[4] at −11, −6, 0, and +6 days, with 0 representing approximately commercial maturity on August 6. The fruits from each plant and each harvest date were kept as separate samples. The whole fruits then were sized into size-classes by means of round-hole screens and also kept separate during germination.

Greenhouse-grown seed

In November 1968 six mother roots of each of five 0-type lines or cultivars of sugarbeets were transplanted from the field to enriched soil in 10-in pots, and induced photothermally. Six photothermally induced plants of the cultivar US H20 also were included. All of the plants were kept in one greenhouse room. Fruits were harvested from the plants between April 7 and May 28, 1969.

In late October 1969, seeds from a single 0-type plant of cultivar C-3 were planted in enriched soil (10-in pots). The seedlings were photothermally induced. Fruits were harvested at about 4-day intervals from 19 plants between April 7 and June 1, 1970.

Dates of first anthesis were recorded for all plants. The estimated time of commercial maturity, based on fruit color, was recorded for each plant in 1969 and for some in 1970. For the 1970 harvest, temperature and humidity were recorded. The heat unit requirements from first bloom to physiological maturity were calculated from the same base temperature (45 F) used by TeKrony (1). Since greenhouse temperatures on sunny days tend to be rather high for a few hours at mid-day, the usual method of determining the mean from the high and low temperatures for each day does not give accurate values. Therefore, the mean daily temperatures were calculated from the actual duration of the temperatures.

[4] (SL 129x133)ms x SP 6322-0.

For any given harvest, all of the fruits collected from the branches of a single plant were kept as a sample, without separation for size or relative maturity. Branches were removed and immediately placed in plastic bags. Fruits were cleaned of bracts and debris and returned to the plastic bags to minimize water loss before weighing. The fruits were air dried in the laboratory and reweighed to calculate moisture percentage at harvest. Fruit-moisture contents were based on the air dried rather than oven dried weights because the samples were completely used for germination tests. In Figure 4, the percentages of moisture in the fruit are expressed on the basis of air dry weight. To convert to an approximate percentage of moisture on a wet basis, an air-dry moisture content of 13% was assumed.

All of the fruits were hand processed to remove the corky material before conducting the germination tests. Immature fruits did not process as easily and relatively less material was removed.

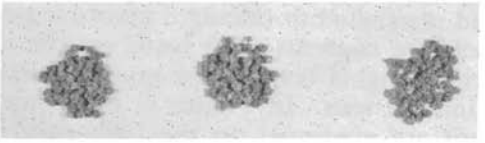
Germination

The seeds were germinated in a germinator at approximately 70 F. The unsoaked, air dried fruits were placed on a double layer of moistened blotters with no covering blotter. All comparisons initially were made for individual plants and the number of fruits indicated are on a per plant per harvest-date basis.

For the Arizona-grown seed, the size-classes for a given harvest were placed on a single blotter. If available, 50 fruits per size-class were used. For the Oregon-grown seed, the technique was modified to place 25 fruits of each size-class for each harvest date on a single blotter. A second replication with the samples randomized on the botter was used, if fruits were available. (This technique minimizes differences in blotter to blotter environmental variation which was inherent in the arrangement used for the Arizona seed and permits a more precise evaluation of the effect of maturity on germination performance.) Germination tests on the greenhouse-grown seeds were conducted with 110 fruits per harvest (a few samples had fewer fruits) which were about equally divided between three replications or blotters. Each blotter contained samples from all harvest dates for a given plant.

Germinated seeds were counted daily for 10 days from the start of a test. After 10 days, fruits from which no seedling had emerged were cut open, examined, and judged as to whether the fruit contained an adequately developed, and presumably viable seed, so that a "corrected percentage germination" could be calculated and reported for each sample. The corrected percentage germination cited in the Tables is based on the number of "good seeds" determined by this examination.

By arbitrary definition, seed samples were considered to be physiologically mature when all seeds, judged to be adequately developed, germinated at least 90% in 10 days. Commercial maturity was based on fruit color (see fruits 69 days after first bloom in Figure 1).



Days after 1st bloom	41	69	80
Moisture %	75	53	26
Germination %	29	99	95

Figure 1.—Sugarbeet fruits from a single plant (cultivar C-2) at three stages of maturity. The intermediate stage is designated as commercial maturity.

Results and Discussion

Field-grown seed

The degree of maturity of the two sugarbeet cultivars markedly affected germination percentages for all fruit sizes (Table 1). The rate of increase in percentage germination was greater between −10 and −5 days than between −5 and 0. When accumulated germination for each size-class was plotted against time, the slopes were very similar for all size-classes of fruits. At commercial maturity, the seeds in the smaller fruits germinated less than 80% when corrected for underdeveloped seeds. Immature seeds also germinated less rapidly (5-day germination percentages, Table 1). The percentage of good seeds decreased with the approach of maturity (column 3, Table 1).

Maturity affected the germination of two cultivars grown in Oregon similarly to those grown in Arizona (Tables 2 and 3). Germination percentages for cultivar (SL 126 × 129)ms × SP 6322-0 increased much more rapidly between −11 and −6 days than those for US H20. In the smaller fruits the percentage of good seeds decreased with the approach of maturity similarly to the Arizona seedlots.

The percentage germination of seeds for all three fruit sizes of US H20 decreased when harvested 6 days after commercial maturity (Table 2). TeKrony (1) noted a similar decrease in germination and a parallel increase in underdeveloped seeds. He suggested that the increase in underdeveloped seeds could have been caused by insect injury, since insecticide applications had been discontinued some time before harvest.

Table 1.—Effect of maturity on germination performance of seeds from 13 plants of sugarbeet variety AI 1 × AI 2 and from 10 plants of GW 823 grown near Phoenix, Arizona in 1964.

Day of harvest	Fruit size[1]	Developed seeds[2]	Germination of developed seeds	
			5 days	10 days
	In./64	%	%	%
AI 1 × AI 2				
—10	12	99.5	34	76
	10	97.5	30	58
	8	91.7	25	50
	7	73.8	18	51
	6	50.3	15	55
—5	12	99.3	47	92
	10	95.7	57	85
	8	81.8	54	76
	7	64.7	40	65
	6	42.6	38	57
0	12	98.6	58	94
	10	92.0	75	92
	8	74.4	48	79
	7	57.5	48	69
	6	34.7	41	73
GW 823				
—10	12	98.1	37	81
	10	97.4	47	75
	8	93.2	40	58
	7	85.1	31	48
	6	62.1	21	32
—5	12	98.3	48	90
	10	95.3	55	84
	8	90.4	51	72
	7	82.2	35	60
	6	69.6	21	54
0	12	96.2	71	91
	10	94.4	73	87
	8	86.9	61	77
	7	78.5	53	74
	6	61.5	46	65

[1] Fruits remained on the screen size indicated.
[2] With 3 exceptions, the number of fruits tested per size-class exceeded 400.

Uncorrected germination percentages (Table 2) indicate that significant decreases in germination can occur because of aborted or non-viable, underdeveloped seeds. By sizing the fruits, most of the non-viable seeds were found to be in the smaller fruits. TeKrony and Hardin (2) recently reported more extensively on this problem for sugarbeet seed grown in Oregon.

Greenhouse-grown seed

The range in maturity, fruit-moisture content, and fruit color used as the index of commercial maturity are illustrated in Figure 1. Commercial maturity and physiological maturity of the

Table 2.—Effect of maturity on speed and percentage germination of seed from 25 plants of US H20 grown near Salem, Oregon in 1965

Day of harvest	Percent developed seeds by fruit sizes—In/64[1]			Corrected percent germination[2]						Uncorrected germination		
				5 days			10 days			10 days		
	14	12	10[3]	14	12	10[3]	14	12	10[3]	14	12	10[3]
—11	97.8	97.3	91.3	35.1	30.3	16.1	64.7	48.5	25.7	63.3	47.2	23.4
— 6	97.5	94.7	84.2	46.1	50.1	38.2	72.8	65.2	49.6	70.9	61.8	41.8
0	98.1	92.7	71.5	41.9	58.8	55.6	84.3	79.2	73.6	82.7	73.4	52.6
+ 6	97.4	91.1	70.4	43.1	57.7	59.1	77.9	74.9	71.0	75.8	68.2	49.9

[1] Fruits remained on the screen size indicated.
[2] Each percentage value based on 584 or more good seeds.
[3] Data for only 22 plants.

Table 3.—Effect of maturity on speed and percentage germination of seeds from 25 plants of (SL126 × 129)ms × SP6322-0 grown near Salem, Oregon in 1965.

Day of harvest	Percent developed seeds by fruit sizes—In/64[1]				Corrected percent germination[2]							
					5 days				10 days			
	14	12	10	8	14	12	10	8	14	12	10	8
—11	99.4	98.4	95.5	80.9	20.4	20.6	12.2	5.6	59.1	42.2	24.8	12.1
— 6	97.2	95.2	83.4	63.4	31.3	53.5	55.3	43.3	87.1	85.0	66.3	55.0
0	98.6	96.0	86.6	63.5	41.1	61.4	68.4	62.7	92.5	91.4	85.7	79.0

[1] Fruits remained on the screen size indicated.
[2] Each percentage value based on 357 to 1203 good seeds.

seeds did not coincide for some of the plants. The range within a cultivar was greater than between the averages of the cultivars (Figure 2). Seeds of some plants were physiologically mature before the fruit coloration associated with commercial maturity. Seeds of other plants did not become physiologically mature until after coloration.

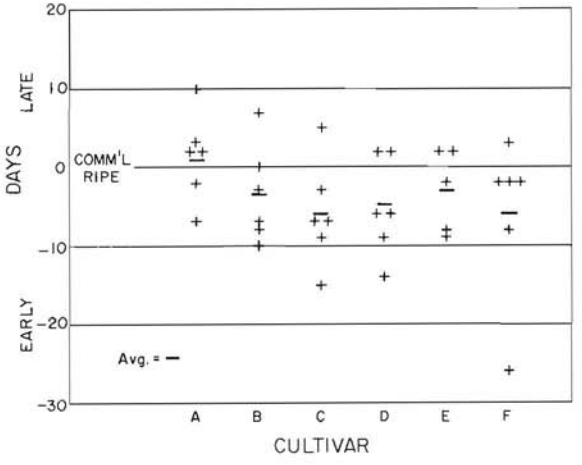


Figure 2.—Relation of physiological maturity (at least 90% germination) of the seed to commercial maturity, based on fruit color, of individual sugarbeet plants.

In this experiment, physiological maturity ranged from 26 days before to 10 days after commercial maturity (Table 4, plants F-6 and A-5, respectively). The interval from first bloom to physiological maturity for seeds on individual plants ranged from 35 to 70 days, with an average of 53. The interval from first bloom to commercial maturity ranged from 49 to 67 days, with an average of 57. Although the average number of days from first bloom to commercial maturity and to physiological maturity differed by only 4 days, commercial maturity was a very poor indicator of physiological maturity of the seed for any given plant.

Table 4.—Relation of physiological maturity of seeds to commercial maturity of fruits for six sugarbeet plants grown in greenhouse in Michigan in 1969.

Plant	Days from first bloom to	
	Physiological maturity	Commercial maturity
F-6	35	61
F-3	52	49
D-6	53	67
D-2	59	57
A-4	61	56
A-5	70	60

TeKrony (1) has reported that the fruits of a hard-bolting cultivar remained green even though the seeds were physiologically mature while an easy-bolting cultivar behaved more typically.

In terms of producing quality seed under commercial conditions, another facet concerns the length of time prior to the onset of commercial maturity that the seeds are physiologically mature or will germinate at least 80%. From Figure 3, plants A-4 and D-2 could be harvested no earlier than two days before commercial maturity to maintain about 80% germination. In contrast, plants D-6 and F-6 could be harvested 16 days and 26 days before commercial maturity, respectively.

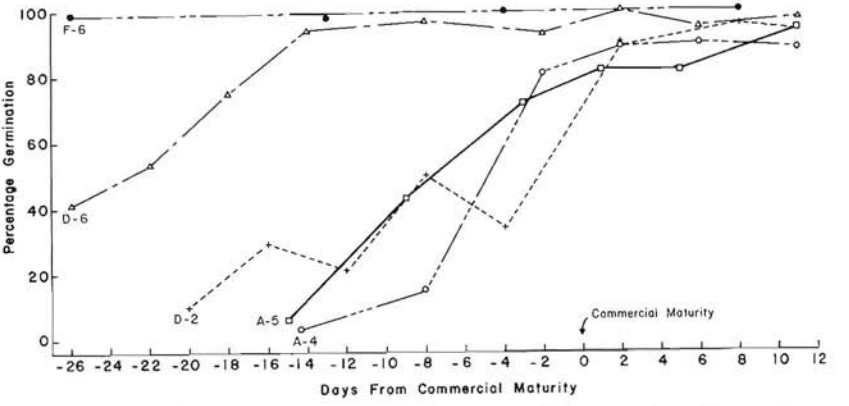


Figure 3.—Extremes in relation of commercial maturity of sugarbeet fruits to physiological maturity of the seeds.

Physiological maturity occurred over a wide range of fruit-moisture contents both within and between cultivars (Figure 4).

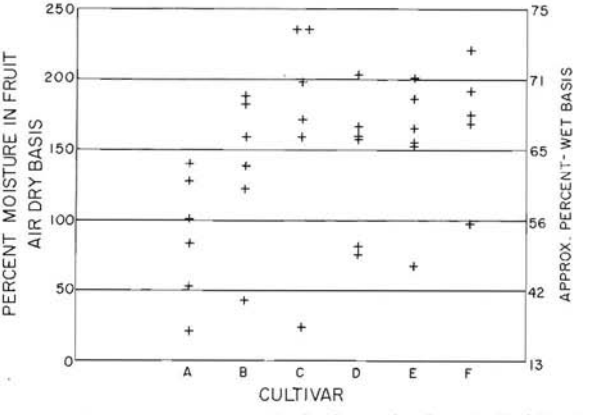


Figure 4.—Moisture content of fruits of the individual sugarbeet plants at physiological maturity (at least 90% germination).

Fruit-moisture content at physiological maturity among individual plants ranged from 29 to 74%, wet basis. The average fruit-moisture content at physiological maturity for 35 plants approximated 63%, wet basis. Seeds of 60% of the plants were physiologically mature at fruit-moisture contents above 65%, but seeds from all six plants of one cultivar were immature at this moisture. Seeds of five plants were physiologically mature when fruit-moisture exceeded 70%.

With the exception of plant C-3, germination percentages for seeds of all plants in 1969 increased rather consistently as maturity progressed. Seeds of plant C-3, harvested five times at 4-day and then twice at 6-day intervals, germinated as follows: 27, 55, 45, 83, 81, 62, and 47%, respectively. The mother plant appeared normal. It seemed important to determine whether this type of germination pattern might be hereditary. The 19 plants grown from seeds of plant C-3 in 1970 also provided a second year's data relating commercial and physiological maturities to first bloom and fruit-moisture content at harvest.

In 1970 the intervals between first bloom and physiological maturity and commercial maturity were about 5 days less than in 1969, but the ranges were nearly the same as the previous year. Fruit-moisture contents for different plants ranged from 35 to 76% at physiological maturity.

The germination patterns of the 19 plants, in relation to maturity, failed to confirm the unusual germination pattern of the C-3 parent plant, thus suggesting that the pattern for the seed of plant C-3 probably was not influenced by special genetic factors. Seeds of two plants, however, required an unusually long time to attain physiological maturity by remaining at a lower percentage germination for three to four harvests before achieving physiological maturity.

TeKrony (1) reported an average fruit-moisture content of about 70% at maximum germination for field grown seed. In this greenhouse study moisture content averaged 63% at physiological maturity, but varied widely between plants within a cultivar. The warmer atmosphere may have accentuated the differences in moisture content. Neither fruit color nor fruit-moisture content can be used as precise criteria for physiological maturity of sugarbeet seeds from a given plant. The failure of fruit color to precisely indicate physiological maturity probably has contributed to some of the erratic germination performance of commercial seedlots of sugarbeet. Whenever estimated commercial maturity precedes physiological maturity, germination will be lower than expected.

Selecting commercial cultivars for early physiological maturity would provide a buffer against lower germination resulting from a lack of complete uniformity in blossoming and maturity in commercial seed fields, and permit more flexible seed harvest without decreasing the germination percentages.

Since moisture contents of the fruits were obtained for each harvest, rates of drying could also be plotted for each plant. Rates of drying (all on air-dry weight basis) were similar for fruits of most plants in a given greenhouse room. The rate of water loss usually decreased sharply once the fruits contained only 45% moisture. The slower rates of drying averaged about 6% moisture loss per day. The average loss in fruit-moisture in 1969 was about 10% per day. In 1970 the average moisture loss was about 15% per day when moisture contents ranged between 84 and 49%. Over this 69-day period in 1970 the ambient temperature in the greenhouse averaged about 70 F and relative humidity about 52%

Under field conditions in Oregon, TeKrony (1) concluded that 900 heat units were sufficient for seed maturity and maximum germination. In the 1970 greenhouse experiment the heat units required for physiological seed maturity ranged from 820 to 1,100 (average 967) for 16 of the plants. (The three other plants had higher requirements because they were slower in reaching physiological maturity and therefore may have been atypical.) With a mean daily temperature of 70 F and a base temperature of 45 F for calculation of heat units, 25 heat units accumulate each day. Thus, the range from 820 to 1,100 is equivalent to about 11 days. With an 11-day range in attaining physiological maturity for a small number of plants within a cultivar, harvesting after accumulation of a fixed number of heat units may not guarantee physiological maturity of the seeds for all plants.

This study re-emphasizes the need for additional selections within sugarbeet cultivars for more uniform bolting, anthesis, and seed maturity to attain greater germination and emergence vigor for space-planting.

Summary

Sugarbeet fruits were harvested 3 or 4 times at 5 or 6 day intervals from the same plants in the field in Arizona and Oregon. Seed harvested 5 to 11 days before commercial maturity did not germinate as well as seed harvested at commercial maturity.

Sugarbeet cultivars, producing seed in the greehouse, were harvested repeatedly to relate germination performance to stage of maturity as measured by days from first bloom, commercial maturity (determined by fruit color), moisture content of the

fruits at harvest, and attainment of physiological maturity (90% germination of adequately developed seeds in 10 days).

Seeds from individual plants within a cultivar differed more than the averages between cultivars. Maturity based on fruit color did not correlate well with physiological maturity. Seeds were physiologically mature from 26 days before to 10 days after commercial maturity. Seeds were physiologically mature when fruit-moisture contents ranged from 76 to 29% wet basis. The interval from first bloom to physiological maturity of the seeds among plants ranged from 35 to 70 days and averaged 53 days. The interval from first bloom to commercial maturity ranged from 49 to 67 days.

Neither fruit color nor fruit-moisture content alone can be used to predict physiological maturity precisely.

Individual greenhouse-grown plants required from 820 to 1,100 heat units from first bloom to attain physiological maturity.

Acknowledgments

The field-grown sugarbeet seeds were harvested, dried, and sent to the author through the kind cooperation of Arnold A. Mast, Manager, Western Seed Production Corporation, Phoenix, Arizona and of Sam C. Campbell, Manager, West Coast Beet Seed Company, Salem, Oregon.

The mother roots for the greenhouse studies were supplied by my colleague, G. J. Hogaboam.

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