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A study of the seed of Apium graveolens Linn: With special reference to the effect of light, temperature, disinfectants, and other factors upon germination.

Elizabeth F. Hopkins
University of Massachusetts Amherst

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Introduction

There is perhaps no one kind of seed which presents more difficulties to the seed analyst when making the several required determinations in the seed testing laboratory than that of celery. There are many uncertainties met with in attempting to adequately measure the viability or seeding value of a parcel of celery seed. The results secured are often erratic and unexplainable. The seed material is apparently sensitive to certain factors. The difficulties due to changes and conditions which apparently play an important role in the life of the seeds are well understood and thus successfully dealt with for many of our more common seeds, but the erratic behavior of certain species, particularly celery, presents a subject for careful study. It would seem reasonable to suppose that in many cases when striving for practical results the influence of one factor against another was measured rather than the actual value or quality of the seed itself. The factors entering into the conditions influencing the vitality of certain seeds as handled in the seed laboratory are but

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* This investigation was conducted in the seed testing laboratory of the New York State Agricultural Experiment Station, Geneva, N. Y., and under the direction of Mr. M. T. Munn, Associate Botanist in charge, to whom the author is indebted for valuable suggestions in conducting the work and for assistance in planning the investigation and presenting the results and conclusions. To those other investigators who have made available apparatus and material, and especially to seedsmen the writer extends most grateful acknowledgments.

vaguely understood and have been largely neglected in research work from a practical standpoint. The purpose of this investigation was a study of the material itself, and to ascertain the possible effect of certain factors influencing the vitality and germination of celery seeds when subjected to such methods of treatment as are generally met with in the ordinary handling of the seed by the analyst in the seed laboratory. Particular attention has been given to the means of measure of viability of the seed stock; and thru physiological studies an attempt has been made to determine fundamental facts upon which to build successful practice. Further, an endeavor has been made to review and examine critically certain considerations now used wholly or in part in general practice.

History of Celery

Sturtevant in his "Notes on Edible Plants" (1919) gives a most interesting and complete account, if not the only history, of celery. According to his notes the celery which we cherish today as one of the choicest table delicacies originated from a plant of habitat extending thruout the marshlands of Sweden south to Algeria, Egypt, and Abyssinia, flourishing also in the mountains of Asia, New Zealand, and California. Coincident with this wide range in habitat is its wide distribution thruout early literature. The "Selinon" of the Odyssey, the "Selinon heleion" of Hippocrates, the "Eleioselinon" of Theophrastus and Dioseriodes and the "Helioselinon" of Pliny and Pallidius are probably the same Apium graveolens in its wild state. Early writers assert that Apium was considered by the ancients as a funereal or ill-omened plant. According to Bretschneider, celery can be identified as "Smallage" in the Chinese work of Kai Sz'mu of the fifth century. Later, it was regarded as having medicinal properties, and we find in the ninth century, medicinal uses implied by Walfridus Strabo. Gamererius, Epitome of Matthiolus 1856, indicates that it was at that time planted in gardens, - "Seritur quoque in hortis," and according to Targioni-Tozzetti, Alamanni in the sixteenth century praises its sweet roots as an article of food. The seamen of the exploring ships in Fuegia found it palatable and healthful, and scorobutic sailors in New Zealand recognized in it a medicinal food. One variety at least was evidently cultivated in France as early as 1623, for we have mention of this by Oliver de Serres. It is interesting to note here the etymology of the word celery, derived stem of the Latin celeritas, meaning haste or speed, application being the reputed rapid action in purifying the blood when taken as a remedy for lethargy or morbidity. The derivation indicates antiquity, and the prevalence of a name deduced from one root denotes a recent dispersion of the cultivated variety. These synonyms are: Danish, Selleri; English, Celery; Flemish, Selderij; French, Celeri; German, Selerie; Italian, Sedano; Portuguese, Aipo; and Spanish, Apio.

"Sellery" is termed a rarity in Parkinson's Paradisus (1629) and Ray's Historia Plantarum (1686) reads, " * * the smallage transferred to culture becomes a milder and less ungrateful." John Evelyn in Acetaria (1699) refers to celery, Apium Italicum as a generous sort of Macedonian parsley or smallage which graces the board of great men's tables and Praetor's feats. In England as early as 1726 the seed seems to have been sold for growing plants to be used in soups and broths. Undoubtedly it was grown on a very small scale for many years. Mc. Mahon names four varieties in 1806, and records show a single exhibitor of the vegetable entered as celery, variety not designated, at the horticultural exhibition held in Worchester in 1848. Appreciation seems to have developed rapidly thereafter, particularly in the regions around New York City and in 1858 Peter Henderson, writing in the COUNTRY GENTLEMAN, claims to have raised thirteen acres, each acre containing 30,000 plants.

According to figures published by the Bureau of Agricultural Economics of the United States Department of Agriculture (1923) the ~~commercial~~ acreage of commercial celery in this country during 1923 was 20,760 which produced approximately 5,546,000 standard crates, or about 17,000 car loads, the estimated value of the crop being $13,219,000. These estimates do not include celery grown on small truck farms which finds its way to local markets, or that produced in home gardens.

Listed in the order of their importance in the celery industry are the following states: California, Michigan, New York, Florida, Ohio, Colorado, New Jersey, Pennsylvania, and Oregon. The geographic distribution of celery growing in the United States is necessarily determined mainly by soil and climatic conditions. In the Great Lakes section the major portion of the crop is grown upon "Hummock" or sandy muck soils. In all localities production is governed by seasonal and climatic conditions, the chief essentials being a clear atmosphere during the day and moderately cool nights. A plentiful supply of moisture is also required.

Botanical Considerations

Generic Description of _Apium graveolens_ Linn. - Members of the genus to which celery belongs are annual or perennial herbs with hollow stems and pinnately divided leaves. The principal species are _Apium petroselinum_, or common parsley, characterized by greenish yellow flowers;

PLATE I

Fig. 1. Bilocular ovary, with one ovule in each loculus.

Fig. 2. Flowers in umbels.

Fig. 3. Flowers with incurved petals.

Fig. 4. Two schizocarps attached to a single carpophore.

Fig. 5. Schizocarps split apart at maturity into two mericarps.

Fig. 6. Schizogenous oil tubes occur in tissue of pericarp.

Apium leptophyllum, or fine-leaved marsh parsley having white flowers with narrow leaf segments; and *Apium graveolens*, including celery and celeriac, which are distinguished from other species by their white flowers and broad leaf segments.

Floral Arrangement of the Umbelliferae. - Flowers actinomorphic, epigynous; perianth and androecium pentamerous; an intra-staminal disc present; gynocium dimerous with free styles; ovary bilocular, with one ovule in each loculus, Fig. I, Plate I.

Development of the Fruit. - The inforesences are compound consisting of many small umbels of white flowers with incurved petals (Plate I, Figs. II and III). The flowers upon being fertilized give rise to brownish-ribbed aromatic schizocarps which are attached to a single slender carpophore or prolongation of the axis (Plate I, Fig. IV). The schizocarps split apart at maturity into two mericarps (Plate I, Fig. V) each mericarp bearing upon its free surface five longitudinal ridges (juga primordia) three on its back (dorsal ridges) and two on its edge near the plane of division. The grooves between the ridges (valleculae) are darker in color, with schizogenous oil tubes (vittae) occurring in the tissue of the pericarp immediately beneath the furrows (Plate I, Fig. VI). The mericarps in commonly accepted usage are referred to as "seeds". In this paper, in accordance with such common usage, the term seeds will be used instead of fruits. However, it should be pointed out that morphologically the seed is united with the mericarp completely filling the cavity and is adherent to the pericarp. A large oleaginous endosperm is present in the upper part of which lies embedded a tiny embryo with upwardly directed hypocotyl. The endosperm as seen in cross section is flat on the ventral side.

Types and Varieties of Celery

There are two general types of common celery, self-blanching and green or winter varieties. The former includes Golden Self-blanch and White Plume, rapid growing, easily blanched tender varieties, especially adapted for fall and winter use. The green varieties are not so easily blanched nor so rapid growing but have better keeping qualities for storage and winter use. Of these, Giant Pascal, Winter Queen, and Emperor are perhaps best known.

Longevity of the Seed

Because of the rather high price of celery seed gardeners are often much concerned as to the possible longevity of any stock of seed held over from year to year. Krout (1921) gives interesting results of tests made upon stocks of seed from various sources in an endeavor to determine the percentage of germination of celery seed of different ages. His results show that upon stocks of seed of satisfactory germination at the end of the first year he was able to secure satisfactory germination at the end of four years and even in the fifth year some results were secured. Thompson (1923) in a table showing the longevity of various vegetable seeds gave three years as the average length of time celery seeds may be expected to retain their vitality when properly handled. Beattie (1925) also stated that after the third or fourth year celery seed loses its vitality rapidly. Certain lots of five-year-old seed, however, were found ~~equal to and~~, according to tests made by the writer, to germinate as high as 91 per cent after having been kept for four years under favorable conditions. It is interesting to note in this connection the extensive experiments undertaken by the United States Department of

Agriculture a number of years ago with buried seeds and their longevity, that celery seed is mentioned among the kinds of seeds of cultivated plants still persisting in vitality after twenty years' burial.

PHYSIOLOGICAL STUDIES

Effect of Light Upon Germination

Several investigators have worked upon the problem of light influences in germination of seeds, tho little seems to have been done with celery seed. The field of viability measurement thru germination is a broad one, and is rendered the more difficult owing to varying requirements of seeds of different genera of the same family, of different species within the genus, and even with seeds of the same species differing only in stage of maturity. Moreover, the temperature factor seems so closely related to light that the two influences have not always been considered separately and thus much confusion and controversy have arisen as to whether the favoring effect of light may be attributed to heat rays or whether the effect is in reality of a photochemical nature. Cieslar in 1883 secured better germination of Poa nemoralis in yellow or warm light than in white light, altho violet (or cold) light gave no better germination than was secured in darkness. Von Liebenberg (1884) showed that Poa pratensis germinated better with a daily alternation of temperature and he maintained that this alternation took the place of exposure of the seed to light. Jodin (1897) stated that light accelerates respiration in seeds to a marked degree. An interesting experiment was performed by him with peas. Two samples of equal weight were kept for four years over mercury under bell-jars, one in the light and the other in darkness. At the end of the given time the 3.452 gram subjected to action of light had absorbed 2.4 c.c. oxygen and produced 1.8 c.c. carbon dioxide, whereas the seed kept in darkness showed but little signs of respiratory activity. Investigations of Heinricher (1902) showed that light exerts a strong influence on the germination of seeds. In some cases, as in Mesembrianthemeum, Portulaca, and *Stapelia variegata*, the seed germinated equally well in light or in darkness. In the case of *Nigella sativa* the seed will sprout only in the dark while seed of *Pitcairnia maidifolia* and *Drosera capensis* will germinate only in the light, those of the latter losing their germinative ability if kept in darkness. The seeds of many cacti, according to this author, also, are hastened in their germination by action of light. Atterberger (1906) reported as results of his experiments with the germination of seeds of cultivated plants, and especially Pinus, that variation in temperature did not equal the beneficial effect of light. Kinzel's paper (1907) "Über den Einfluss des Lichtes auf die Keimung "Lichtarte" Samen" has particular significance in its relation to experiments performed by the writer. Kinzel found that seed of *Nigella sativa* was incapable of germinating in a lighted seed-bed, but that the endosperms were so affected by light that even when transferred to darkness they refused to germinate. The same seed in total darkness germinated 94 per cent in four days. Kinzel described a dark yellow material resembling xanthophyll which accompanied the seeds germinated in darkness but was lacking in seeds germinated in light. This dye substance varied in amount according to the intensity of the light, and he suggested that it doubtless plays an important part in the nourishment of the germinating seed in changing carbohydrates. Chlorophyll seems to be formed in a normal way with seed such as *Nigella sativa* which suffers injury from light. On the other hand, this investigator further stated that light-requiring seeds as Poa spp. probably utilize the light in the formation of chlorophyll. Later it was demonstrated that the united action of light and temperature brought about this unusual condition in Nigella, while the seeds at 10 degrees or 15 degrees C. germinated more slowly than if darkened, (in four weeks instead of four days) but they did not reach that peculiar dormant condition which Kinzel designated as "Lichtarte." According to Kinzel, seeds may be made lichtart by exposing them to illumination of gas light for 24 hours after a period of germinating in darkness, and seeds brought into red light after 24 hours' exposure to gas light gave the same results. Kinzel's tests with seed collected by himself proved that freshly harvested Poa pratensis required light for germination as did also freshly harvested celery seed. He found that fresh Poa seed in the light of 20 degrees for 10 days germinated 95 per cent. In darkness, under the same conditions, 0 per cent germinated. The same was true of freshly harvested celery seed. Kinzel tried all light of the spectrum from red to violet and observed that all light sensitive seeds gave a higher germination at the bright end of the spectrum while there was a considerable decrease toward the violet or dark extremity. Kinzel's experiments as described were made on sterile filter paper in petri dishes equipped with covers of glass of the various colors. Green light was found to be optimum for Poa pratensis, but Kinzel affirms that with very fresh seed red light may be substituted to good advantage. A difference, also, was noted in the appearance of the sprouts germinated in these different lights; for example, in yellow light the sprouts were fully five centimeters in length and of a healthy live green color while in violet light they were of an emaciated yellowish-green. Kinzel recognized, however, that certain seeds behave differently in different lights, according to the temperature accompanying the particular light, as for example, *Asphodelus ramosus* seemed to receive injury from dark blue light at 14 degrees C., while at 20 degrees the reds (red to yellow) seemed to exert similar detrimental effect. An optimum, lay with all temperatures, was found in yellow light. One of the most striking instances of the divergent requirements of related species is seen in *Nigella damescens* which germinates best in the center of the spectrum, or in green light, while *Nigella sativa* demands complete darkness for germination.

Observations made by Pickholz (1911) showed that seeds of *Poa pratensis* germinated normally in the dark only when heated for a time. The influence of direct sunlight he attributed to heat rays which brought about an increase in temperature. The light rays were also observed to exert a slight influence on germination which he considered as a possible result of their transformation into heat. Baar (1912) reported that germination of Amaranthus seed was hindered by light, and that the younger the seed the more sensitive it was to light. Also, the germination of fresh seeds of *Clematis vitalba* at low temperatures was favored by darkness, that of older seeds by light, while seeds of *Begonia semperflorens* invariably germinated better in light. Lehmann (1912-13) has made extensive studies of the effect of light, temperature, and seed germination, his general conclusions being that altho in many cases temperature determined whether or not seeds under investigation should react to light, in other cases temperature did not seem to justly modify light influence. The temperature range of germinability in light was found to be considerably greater than that in darkness. In another series of experiments Lehmann, working especially with seeds of Lythrum salicaria proved that proteolytic enzyms favored germination in darkness of seeds normally requiring light. Also, his results show that strong illumination produced much earlier and more abundant germination in seeds of Lythrum salicaria than was obtained in seed not so exposed. Lehmann's theory is that light acts catalytically upon the albumen in the seeds.

Reilung (1912) reported light as a favorable factor to germination in the case of Poa pratensis, Alopecurum pratensis, and Festuoa pratensis, particularly immediately after harvest. As the seed aged, light seemed less important. Pieper (1913) tried light effects on the germination of Poa pratensis, Apera spica-venti, and the Lolium spp. finding that each responded to light better than to darkness.

Ottenwälders (1914) experimentation is similar to that of Lehmann in which he shows that germination of seeds depends largely upon temperature, but both this requirement and that of light were found to differ in general with the specie as well as individually with age. The light requirement as regards intensity is closely related to temperature, the former increasing as the latter is lowered. The illumination period is also related to temperature, but more closely to light intensity. Seeds which are sensitive to light he found to be also strongly influenced by weak acids. Ottenwalder's observations seem to give further support to Lehmann's hypothesis of the catalytic influence of light.

Carl (1914) studied illumination of ultra-violet rays finding that ultra-violet rays exeroise an injurious influence upon sprouting plants, as regards both germination and subsequent development in the early stages. This he claims not to be due to warmth but to chemical influence of the rays.

Gassner (1915) worked chiefly with seeds of the Onograceae in an attempt to prove unfavorable action of light at extreme germinating temperatures. He showed that seeds require a stronger light at low temperatures. Altho his studies are not conclusive he emphasized with Lehmann the favorable action of light as a catalytic agent within the seed. Raciboski (1916) found tobacco seeds locally germinated very poorly if at all in darkness, whereas Gassner (1915) pronounced seeds of tobacco among those insensible to light. In line with this controversy Honing (1916) conducted tests, results of which indicated that seeds of Delhi tobacco germinate only a small percentage in darkness, while those of other varieties germinate in darkness as completely as in light. Morinaga (1925) in his paper on "Temperature and Germination" states that light was effective in germination of celery seeds only when unfavorable high temperatures were used. Light also affected the germination of Bermuda grass seed when acting in combination with poor temperature alternations, but not in favorable alternations.

A number of experiments were performed by the writer with the object of determining the effects of light on the germination of both old and newly-harvested celery seed. The old seed used was of the Winter Queen variety of 1922 stock supplied by a reliable seedsman, while the new seed (also seed of the same variety) was freshly harvested in early September from plants grown by the writer. In every case the method used to germinate the seeds was in principle that of the bell-jar (BJ) with filter paper, candle drip and wick. Black photographic paper was pasted over the covers and fitted closely around the glass itself to exclude all light from the dark tests (Plate II). Most of the experiments were conducted in a greenhouse where temperature by day was maintained at

PLATE II

Types of bell-jar (BJ) set-ups used in the darkness vs. light experiments.

approximately 30° C. and a night temperature lowered often to 15° C. Old and new seed both in light and darkness were run in series of eight tests each. The following table shows the results of such an experiment:

Table 1.- Showing results of germination of old and newly-harvested celery seed in darkness and in light

	In Darkness Percentage germination		In Light Percentage germination	
Test Number	Old seed	New seed	Old seed	New seed
1	80	31	74	42
2	89	44	73	39
3	72	49	79	44
4	66	43	50	57
5	70	39	55	38
6	76	42	52	41
7	85	43	40	48
8	69	42	42	41
Average	75.8	41.6	58.1	43.7

In this series of tests the new seed germinated slightly better in light, whereas the old seed in this experiment did better in darkness.

Another type of set-up for the light-versus-darkness tests seemed to have certain advantages over the tumbler outfit in that it was more simple and permitted running 24 sets of 100 seeds each under identical conditions of moisture, light and temperature. This apparatus consisted of a galvanized metal tank 15 x 21 inches and 5 inches deep, holding a metal tray or shelf having 24 aperatures in it each one inch in diameter. Candle drips over these holes supported filter papers bearing the seeds. Candle wicking supplied constant and uniform moisture supply up to the filter paper as in the case of the tumbler outfit. The tests were each individually covered with watch glasses inverted over them. One of the tanks was further equipped with a tight-fitting cover to exclude all

PLATE III

Fig. 1. Showing sets of 100 seeds of celery germinated in light. Seeds on filter paper moistened from below by wicking.

Fig. 2. Showing sets of 100 seeds of celery germinated in darkness. Seeds on filter paper moistened from below by wicking.

light but permitted aeration thru vents, while the other tank was given maximum exposure to light. In this particular experiment, the results of which are given in the following table, new crop seed of the Golden Self-Blanching variety was used with three-year-old seed of the same variety. The apparatus used is shown in Plate III.

Table II. - Showing the results of germinating old and new celery seed of Golden Self-blanching variety in light and in darkness.

	Percentage germinated in darkness		Percentage germinated in light	
Test Number	Old seed	New seed	Old seed	New seed
1	60	29	45	41
2	59	20	56	27
3	40	18	45	35
4	55	33	68	20
5	25	28	34	24
6	31	17	38	17
7	34	32	41	51
8	36	24	52	25
9	24	26	38	49
10	42	11	44	28
11	52	28	34	26
12	54	29	46	22
Average	39	18	32	26

It will be noted that here again the average germination of the new crop seed in light was about six per cent higher than the comparative average germination of the new seed in the darkness. The old seed also in this instance did better in light. It is worthy of note that all of the series of both old seed and new seed molded badly in the darkness, while on the other hand in light both lots were comparatively free from molding. Comparative appearance of these two lots are shown in Plate III.

Effect of Red Light. - A series of eight tests of 100 seeds each from lots of five-year-old seed and the freshly-harvested seed were arranged for germination and exposed to photographic red light only for a period of 28 days. Comparing the results with those of check tests germinated in daylight, which were 58 per cent for the old seed and 43 per cent for the new seed, it is found that the red light used seemed to be slightly beneficial to old seed but, contrary to the affirmation of Kinzel, red light in these tests did not prove of benefit to the new seed. It should be pointed out that in connection with these experiments with the red light, as indeed with practically all of the work of other investigators mentioned above, that nothing was known of the photometric value of the red glass used. Until these photometric values of the glass are definitely known not much can be done in the way of comparison or measurement of light influence.

Effect of Ultra-Violet Rays. - Schanz (1919) claims to have obtained better results in germination with certain seeds under violet rays than under common glass or in ordinary daylight. This was first observed in the case of lettuce seed. Later, Schanz and Schwede working jointly with seed of stinging nettle (Brennesselsamen) on the problem of light influences found that seeds in the ultra violet germinated six to seven days earlier than those in ordinary light. Also, germination percentages were higher as shown by the readings made on the fourteenth day:

I	Common light	20 per cent
II	Windowpane glass	23 per cent
III	Raw glass	56 per cent
IV	Euphos b	58 per cent

(Raw glass is understood to be unrefined glass. Euphos b is known as a filter glass cutting out all rays of a wave length shorter than 420 uu.)

The size and vigor of the young seedlings correlated with the increased rate of germination, the hardiest and largest plants appearing as result of growth under No. IV or the ultra-violet rays. The experiment was repeated giving similar results. Even more striking was the case of beans germinated according to the four methods. Here are shown plainly in photographis plates accompanying the article the seeds in pots exposed to Euphos b excelled those in the free and the glass-grown pots. It is markedly noticeable, too, that the seeds in pots exposed to Euphos b developed more dense foliage and the plants were larger than those in the pots exposed to a Euphos a glass.

Professor O. L. Clark of the Massachusetts Agricultural College in a letter to the writer stated that his experiments with lettuce failed to show any convincing influence of ultra-violet rays on germination. Popp (1925) did not find the ultra-violet rays to be beneficial to germination and subsequent plant growth. In his paper on the effect of ultra-violet rays on the germination and early growth of plants the following generalizations are given: (1) Exposures of dry seeds to the full ultra-violet of a mercury vapor arc have little or no effect on later germination and growth even after 188 hours exposure. This may be due to the inability of the short rays to penetrate the dry seed coats. (2) Exposures of less than two hours duration on soaked seeds that have not yet begun to sprout do not have a marked effect on germination. Probably here again there is not enough penetration of the short rays in so short a time to cause any permanent injury. (3) Longer exposures to the open arc decrease the rate and the amount of germination, and inhibit growth and development, finally causing death of the plants. The wave lengths below 300 uu are more effective in this respect than those above 300 uu. (4) In general, the cotyledons of seeds exposed to ultra-violet seem to have difficulty in emerging from the seed-coats, but if they get thru they are not seriously injured by the short rays until after long exposures (120 hours). (5) Bacteria and general damping-off fungi do not develop in the rays of the open arc, but will if the region below 300 uu is screened off.

Jacobson (1927) claims that harmful effects in X-ray treatment of seeds resulted in "hard" wave lengths or too long continued exposure, but that mild doses of "soft" X-ray may be beneficial to seeds. In one series of experiments which he reported, potted plants grown from rayed seeds grew faster and more vigorously than those grown from unrayed seeds. They flowered and fruited from one to three weeks earlier, and the yield was from 15 to 170 per cent greater, the fruits being always more numerous and often larger individually. Furthermore, time seemed to have little effect in dimishing the effects of the raying, since seeds kept three months after treatment did nearly as well as those planted immediately after exposure to the rays.

Results of experiments performed by the writer seemed to indicate that celery seed may be mildly stimulated in germination thru violet rays. In these experiments a quartz mercury vapor arc without any light filters was used. The seeds used were from two lots previously referred to as old seed 1922 stock and newly-harvested 1926 stock. The lots were arranged for germination by the ordinary bell-jar (BJ) method, sets of 8 x 100 seeds from each lot being placed 18 inches from the arc. Covers were removed from the bell-jars to permit full penetration of the rays and the seeds were exposed for one hour every other day thruout the twenty-eight day period. Temperature differences as recorded each time showed no greater rise than 2 to 2 1/2 degrees F. due to heat from the lamp. The results obtained from these tests are as follows:

Table III. - Showing the effect of violet rays upon the germination of both old and newly-harvested celery seed.

Test Number	Old seed	New seed	Check tests		
			Old		New seed
1	74 %	44 %		—	
2	79	46		—	
3	81	51		—	
4	88	48		—	
5	83	38		—	
6	89	40		—	
7	75	57		—	
8	85	41		—	
Average	79 %	45 %	58 %		43 %

It will be observed that the average per cent. for all tests of the 1922 seed was found to be 79.2 per cent as against 75.5 per cent for the check or control tests of the same lot of seed. For the 1926 or newly-harvested seed the average per cent. germination of the violet-rayed seeds was 45.6 per cent as against 43.6 per cent for the check tests. First sprouts appeared one day earlier in the seeds exposed to violet rays than did those from the unrayed, check or control lots.

Observations made in addition to the germination response included the appearance of a note-worthy yellow stain which appeared on the filter paper around each seed from the 1926 lot (newly-harvested seed) after the first hour's treatment. This stain was not evident in the other lot nor could any color be detected in the check tests. The writer was unable to determine at the time the exact nature and cause of the color matter.

Later examination of the remaining seed from that lot showed some discoloration resulting from seed soaked in tap water which was slightly alkaline. This was not so apparent when distilled water was used. Seed taken from another lot behaved similarly, showing that the condition was not peculiar to new seed only. Kinzel (1907) mentions a yellow material or a "Xanthophyll" dye-stuff which appeared and accompanied seeds germinated in darkness but did not appear in seeds germinated in light.

Altho mold was entirely eliminated and a somewhat earlier and higher per cent of germination was obtained in the tests described above, certain limitations should be noted, such as discolored root tips which occurred on the germinating seeds, this being especially noticeable directly after treatment. The character of the shriveled brown tips and lack of root hairs resembled injury from burning, altho the thermometer did not show a sufficient change in temperature to account for this effect.

Emergence of the cotyledons seemed likewise to verify the statement made by Popp and others, namely, that the cotyledons of seeds exposed to ultra-violet rays or light have difficulty in emerging from the seed coat. In observing these tests it was noted that frequently the radicle from the rayed seeds became twisted and distorted in its endeavor to separate the cotyledons from the seed coats, and often the cotyledons appeared under developed, due to possible lack of nourishment from dearth of root hairs. On the whole the results of these tests did not seem to substantiate entirely those of Schanz.

Effect of Temperature Upon Germination

The potency of temperature in seed germination was early recognized by Haberlandt (1875), who suggested temperature effects upon water intake of seeds as a possible cause of the favorable effect of temperature alternations upon germination. This viewpoint was later regarded as untenable, it being pointed out that most seeds whose germination is favored by temperature alternations take up more water than the minimum required for germination. Liebenberg (1884) showed that in seed germination the reserve materials made available at any given temperature were largely used up in respiration, but that a slight surplus becoming soluble at higher temperatures is available for growth when the temperature is lowered with subsequent reduction in the intensity of respiration.

Vanha (1898) called attention to the fact that differences in temperature between different parts of the seed, the germination-bed, and the outer air following a sudden temperature change cause different gas densities which may set up lively gas movements leading to removal of carbon dioxide and renewal of oxygen, conditions favoring increased respiration and probably germination. Others who have contributed valuable information concerning temperature effects upon germination are Burchard (1892), Pammer (1892), Gassner (1910-1915), Lehmann (1911), Pickholz (1911), Reilung (1912), Heinricher (1912), Harrington (1923), and Morinaga (1925). These investigators generally advocate a definite daily alternation of temperature, tho Gassner found that only a few hours at low temperature induced maximum germination of seeds of _Paspalum dilatum_ which would not germinate well without previous exposure to low temperature. This effect was regarded by Gassner to be a matter of oxygen relations. Lehmann (1911) found and showed a beneficial effect due to temperature changes without definite daily alternations. Heinricher (1912) also proved that a similar favorable effect was produced in some cases by temperature change once in five days. Harrington (1923) from extensive work on the effects of temperature alternations with Kentucky bluegrass, redtop grass, Bermuda grass, celery, and certain flower seeds, found that celery seed germinated almost as completely at nearly constant low temperatures as with temperature alternations, tho it germinated more slowly. However, as the germination temperature increased a relatively wide alternation (10 degrees C.) became imperative and still wider alternations (15 degrees to 20 degrees C) did no harm. The favorable effect of the alternations is held not referable to the effect of the extreme or mean temperatures but as the result of the changes in temperature. Even the slight fluctuations in the temperature of the cool germinating chambers were no doubt partly responsible for the high percentages of germination at low temperature. However, these are probably insufficient to explain the results entirely if the seeds required as wide alternations at low temperatures as at high temperatures. Other factors seem to be involved as explained by further experiments by Harrington, in which 96 simultaneous tests of celery seed from a single unusually sensitive lot were made in different parts of a single chamber which was heated from below by a gas burner during several hours of each forenoon and cooled each afternoon by a stream of cold water in the top of the water jacket around the chamber. The upper and lower temperatures were controlled by thermo regulators, and the lower temperature was held for about fifteen hours of each day. The seeds in the more rapidly cooled parts of the chamber germinated much more quickly and completely than did those in the other parts of the chamber, tho the extreme upper and lower temperatures reached were very nearly the same in all parts of the chamber. The actual range in percentage of germination in different parts of the chamber was from 0 to 32 per cent in 7 days, from 0 to 58 per cent in 9 days, from 11 to 81 per cent. in 11 days, from 41 to 91 per cent in 14 days, and from 53 to 95 per cent. in 21 days. After 21 days the seeds which had occupied the least favorable positions and had germinated most poorly were put in the most favorable positions, with the result that their germination soon increased to equal that of the seeds originally in the more favorable positions. Similarly, when the celery seed was daily transferred between two chambers constantly maintained at different temperatures and the cool chamber was cooled by a block of ice above the water jacket, the seeds germinated somewhat better if placed on the top of the cool chamber than if placed lower in the chamber where the temperature changes were less abrupt. In the tests discussed, the temperatures in the positions in which the seeds germinated best were almost always somewhat lower than in other parts of the chamber. The differences in temperature were not, however, commensurate with the corresponding differences in germination. In the more rapidly cooled and constantly somewhat cooler parts of the cool chambers congestion currents of air must have been more lively than in other parts, and this may have led to a significantly better renewal of oxygen in immediate contact with the seeds, a suggestion made by Vanha (1898). Also there was a constant tendency in the cooler parts of the chambers for water from the air which had become saturated in the warmer parts of the chamber to condense upon the surface of the seeds. This condensation water would be presumably saturated with oxygen which would be immediately available for the use of the seeds. This is, of course, admitted by Harrington to be only a possibility. According to Harrington, high temperatures should not be long maintained, and he advocates transferring between two chambers rather than heating and cooling a single chamber. He also holds that for best germination the temperature after its initial rise to a higher degree should fall at least as low as 21.5 degrees C. for at least 12 hours of the day, and should be as low as 20 degrees for several hours each day. Harrington found, however, that different lots of the same kind of seed sometimes vary widely in temperature sensitiveness.

In a recent paper Morinaga (1925) gave an interesting account of his work which included extension of previous studies done on the effect of alternations of temperature upon the germination of seeds. In his experiments he used a greater variety and range of alternations, especially 5°, 10°, and 15° C. as the lower temperatures. He tried also the effect of alternations on seeds under water and in reduced oxygen pressure as well as on moist substratum in the usual oxygen pressures. The following kinds of seeds were used in the experiments: Bermuda grass, Canada bluegrass, cat-tail, celery, and Japanese barberry seed. The material was all harvested in 1923 and in certain cases the experiments were run both in the spring and in the fall of the following year for the purpose of observing the effects of the period of dry storage upon germination behavior. The seeds were placed in constant temperature ovens regulated to temperatures of 10°, 15°, 22°, 27°, 32°, and 38° C. The alternations were secured by daily transfer from one constant temperature to another. This meant a sudden heating or cooling of the seeds dependent upon the transfer made. Two types of germination chambers were used: (1) the seeds being placed on moist filter paper in petri dishes, and (2) seeds kept at the bottom of 100 c.c. Erlenmeyer flasks filled with distilled water. Generally the exposure to the higher temperatures was for 6 hours, and to the lower temperature for 18 hours. Some experiments were carried out to compare the effect of the reverse conditions, namely, 18 hours at high temperature and 6 hours at the low temperature. In one experiment a series of duration periods extending from 40 minutes to 8 hours was also tried. The results of germination tests on moistened filter paper showed that celery seed responded well to a great number of alternations, that it germinated fairly well in low constant temperature (10° C.) but not at all in higher constant temperatures. Morinaga also reported that celery seed germinated about the same in water as on moist filter paper, tho in certain cases somewhat better under water than in moist filter paper, both at low constant temperatures and at alternations of low and higher temperature.

After a study of 568 tests the writer is convinced that a sharp daily alternation of temperature with light is one of the prime requisites for the successful germination of celery seed. Tests run at room temperature, at constant 20° C. and at constant 25° C. in every case failed to give as high final percentages as those where the seeds experienced a definite change from 10°C. to 25° C. In a certain series of tests which were repeated in the same region of the greenhouse later when the house was used for mushroom culture and maintained at approximately 15 ° C., it was interesting to find that the average of these tests reached 81.1 per cent., showing in this case only a slight difference in favor of the alternating temperature as compared with the low, cold, constant temperature, tho markedly fewer sprouts appeared at the time of the preliminary count, indicating that germination was probably retarded by the cold. A warm constant (30° C.) temperature, on the other hand, seemed to throw the seeds into a state of dormancy from which they failed to germinate readily, the highest average from six such tests being only 28 per cent. These results can best be shown in tabular form.

Table IV. - Showing results of comparative tests of celery seed at low constant temperature, alternating low and high temperature, and high constant temperature.

Constant 15° C. Temp.			Alternating 10° to 25° C. temperature		Constant 30° C. Temp.	
Test Number 1	Pre.	% Final	Pre.	% Final	Pre.	% Final
1	19	79	42	88	4	26
2	16	82	51	89	6	28
3	22	81	68	86	2	31
4	19	76	40	88	3	40
5	11	85	72	89	7	25
6	27	84	60	85	5	20
Average		81		87		28

Plainly, these results substantiate the findings of Harrington and others that it is highly essential to quick germination to have a sharp daily alternation of temperature. The final results secured from low constant temperature may closely approximate those secured by an alternation; however, high constant temperatures are always to be avoided in germinating celery seed since this condition of high constant temperature seems inducive to dormancy, particularly in the more sensitive lots of seed.

The Effect of Maturity on Germination

For purposes of experimentation as to the ability of celery seed to germinate at different stages of maturity the writer collected green, immature seed and also well ripened seed. Series of tests from these two lots were placed to germinate in bell-jars kept in a refrigerator near ice. These tests were continued thru 54 days. During this time no sprouts had appeared. Because of the fact that the tests had molded rather badly they were then transferred or brought out into light and room temperature following which four seeds from the immature lot germinated. Most of the ungerminated seeds were found to be soft when pressed and considered dead. The seeds which remained firm after this period were continued for several days in the light, thoroly dried, and later, again given optimum conditions for germination. but no further response could be induced. The well ripened lot following the same kind of treatment failed to show any signs of viability until after they were removed from the cold. Three days after exposure to heat and light this mature lot of seed gave a germination of 66 per cent. Another lot of seed freshly harvested was spread out to dry for several days on paper in a warm, fairly well ventilated attic. Later, a series of 4 x 100 seeds from this lot were placed to germinate both in darkness and light at an alternation of 20 to 30 ° C. It was noted that the fresh seed dried in this manner was slow in its response under both conditions. On preliminary count the average germination from the set placed in darkness was 6.5 per cent. while those in light gave 12 per cent. Final percentage secured from the seeds in light was 64.5 per cent. The behavior of the set which was kept in darkness was noteworthy since on September 3 or at the time of final count only 26 per cent. of the seeds had germinated. The tests were continued 31 days. The seeds which had failed to sprout were then carefully transferred to fresh filter papers (profuse molding having taken place on the original papers) and the bell-jars were then brought into light. This test was continued 30 days longer when, as a final reading, 51.5 per cent. of sprouts was obtained, thus closely approximating that secured in a much shorter time on the lot exposed to light thruout the period of the test.

One other experiment showed an unusual behavior of newly-harvested seed. The seed material here used was from still a different lot harvested August 27. The seeds dropped quite readily from the umbels, showing them to be fairly well matured or ripe. These were placed immediately in bell-jars in sets of 4 x 100 seeds to germinate at 20 to 30° C., both in darkness and in light. On the 12th day the seeds kept in the darkness had germinated 75.2 per cent, while those in light gave 80.5 per cent germination. Apparently germination was completed in this time for, altho the test was continued, no more seeds sprouted. Perhaps the seeds used were of exceptionally strong vitality, which may account for the remarkably quick response.

The series of experiments conducted seem to show that green seed as well as seed which is only slightly immature does not germinate well under constant cold conditions; and if too green the seed fails to respond well with other treatment. Light, together with quick change in temperature, seemed effectual in causing slightly immature seed as well as fully ripened seed(both freshly harvested and aged) to germinate. Freshly-harvested seed is likely to be slow, tho not always, in responding.

Effect of Enzyms Upon Germination

From a review of the literature the writer was unable to find any record showing that celery seed had been treated experimentally with an enzym, altho several other kinds of seed seem to have been subjected to the influence of various solutions for the purpose of studying their effects upon germination.

Thompson (1896) experimented with seeds of barley, oats, peas, wheat, rye, white and yellow clover. He reported but little difference in appearance between old and new seed of these kinds as seen in cross section except for slight change in color tone, altho the old seed germinated much slower. He therefore undertook experiments with old seeds which were soaked in solutions of diastase and pepsin for 24 hours, then thoroly washed with distilled water and subjected to germination conditions. The enzyms used were prepared by dissolving commercial diastase and pepsin in water. Also, a second diastase was made from the extract of fresh barley seed (malt) and glycerine water. Some of the most striking results as given by Thompson are as follows: Barley which soaked in water germinated 4.5 per cent; when treated with 5 per cent diastase this same lot gave 35 per cent. germination, and with diastase (10 per cent) a germination of 48 per cent. was secured. A 5-per cent solution of pepsin in this case raised the germination 10 per cent higher or to 58 per cent. Other comparative results are best shown in a tabular statement as follows:

Table V. - Showing the results of seed treatments with enzyms

Kind of seed used	Nature of the treatment			
	With H_2O	With Diastase		With Pepsin
		5 % sol.	10 % sol.	
	%	%	%	%
Oats	16	47	54	39
Corn	16	49		39
Peas	5	22		
White clover	17	50		18
Yellow clover	7			12

Rye and wheat seed 25 years old did not respond to enzym treatment, tho in general , as is indicated by this investigator's results, an increase in germination was obtained in seeds supplied with diastase, and the same advantageous tendencies were apparent, tho to a less degree, with the use of pepsin in place of diastase.

Waugh (1896-97) conducted extensive experiments with cucumber, tomato, radish and watermelon seed using diastase and pepsin. In his tentative generalizations Waugh reported that results of his experiments in which it appears that the seeds were soaked for various lengths of time in the solutions, seemed to indicate that the percentage of germination is increased by soaking seed in enzyms, and within limits, these beneficial results increase with the strength of the solution. One series of tests described by Waugh is that of twelve-year-old tomato seed which when soaked in water gave 34 per cent. germination, but when soaked in diastase gave a corresponding 70 per cent. germination. Another sample germinated 12 per cent with water as compared with 85 per cent germination after diastase treatment.

Marquenne (1900) studied enzyms in the seeds themselves from the healthy live green color while in violet light they were of an emaciated yellowish-green. Kinzel recognized however, that certain seeds behave differently in different lights according to the temperature accompanying the particular light, as for example <u>Asphodelus ramosus</u> seemed to receive injury from dark blue light at 14 degrees C. while at 20 degrees the reds (red to yellow) seemed to exert similar detrimental effect. An optimum lay with all temperatures, was found in yellow light. One of the most striking instances of the divergent requirements of related species is seen in <u>Nigella damescens</u> which germinates best in the center of the spectrum, or in green light, while <u>Nigella sativa</u> demands complete darkness for germination.

Observations made by Pickholz (1911) showed that seeds of <u>Poa pratensis</u> germinated normally in the dark only when heated for a time. The influence of direct sunlight he attributed to heat rays which brot about an increase in temperature. The light rays were also observed to exert a slight influence on germination which he considered as a possible result of their transformation into heat. Baar (1912) reported that germination of Amaranthus seed was hindered by light, and that the younger the seed the more sensitive it was to light. Also, the germination of fresh seeds of <u>Clematis vitalba</u> at low temperatures was favored by darkness, that of older seeds by light, while seeds of <u>Begonia semperflorens</u> invariably germinated better in light. Lehmann (1912-13) has made extensive studies of the effect of light, temperature, and seed germination, his general conclusions being that altho in many cases temperature determined whether or not seeds under investigation should react to light, in other cases temperature did not seem to ~~to just~~ ~~to~~ modify light influence. The temperature range of germinability in light standpoint of function in preservation of vitality. He suggested that the vitality of seeds is dependent upon the stability of the particular ferment present, and that the prolongation of vitality in seeds that are kept dry is due to the better preservation of the enzyms. However, later in 1904 Duvel pointed out that if the suggestions made by Marquenne were true in every sense then dead seeds should be awakened into activity by artificially supplying the necessary enzyms, which of course has never been accomplished.

Stone and Smith (1901) presented evidence in favor of increasing the percentage of germination in certain old seeds by the artificial use of enzyms. The experiments included the selection of solutes known to exist in many seeds and seedlings as ferment or enzymes, namely, diastase, pepsin, trypsin, and also certain amides, such as asparagin and leucin. The strength of the solution used varied from .1 per cent to 2. per cent and the seeds were soaked 12 hours after which they were rinsed with water, and placed in a Zurich germinator, excluded from light in a room with fairly even temperature. One hundred seeds each of barley, alfalfa, buckwheat, Canada field peas, crimson clover, cucumber, rape, rice, seradella, and vetch were treated as described. With a single exception the results which were secured from the use of asparagin show an increase in germination in the treated average over the normal average. Precisely the same percentages of germination for both the normal and treated seed were obtained in the case of the Canada field peas with asparagin. The experiments with pepsin also showed an increase in the average over the normal average in the germination of crimson clover and cucumber. In this connection it seems worthy of note that all of the pepsin solutions except the 0.1 per cent (which accelerated germination) gave results in the direction of a retardation of germination. The effects of diastase following the same methods of treatment showed results favoring the use of diastase, tho a troublesome feature here was the formation of molds.

Duvel (1904) experimented further on the question of determining how enzymes function in the preservation of vitality in seeds. Naked radicles from the embryos of living and dead beans were ground and macerated in water for one hour. The filtrate was then added to dilute solutions of starch paste. The solutions from the living embryos gave rise to energetic hydrolytic action. In all cases hydrolysis was sufficiently advanced to give a clear reaction with Fehling's solution. The solutions extracted from the radicles of the dead beans also gave reactions sufficiently clear to demonstrate that some ferment was still present. These and similar results from other tests led Duvel to believe that the loss of vitality in seeds is not due to the disorganization of the enzymes present, altho there is probably a close relationship between lack of vitality and decomposition of enzymes.

With further reference to the use of stimulants in seed germination it might be mentioned here that Morinaga (1925) found that nitrate solutions did effect the germination of celery seed.

In experiments performed by the writer in which five-year-old seed and freshly-harvested seed were soaked for 24 hours in a 5-per cent solution of Taka diastase, the benefit derived from enzyme application was not so pronounced as in some of the cases described above, altho results pointed in the direction favoring such treatment. From the same lots seeds were simultaneously put in to test in the laboratory after having been soaked 24 hours in water, and a check series of untreated seeds was also under observation. The seeds were germinated in a daylight germinator in sets of 8 x 100 and extended thru a period of 28 days. The results of the test are shown herewith:

Table VI. - Showing the results of treatment of celery seed with certain solutions. Results given in terms of percentage of germination.

Kind of treatment	Newly-harvested seed Average per cent	Old seed Average per cent
Check tests	40.3	65.0
Soaked in water	41.0	75.5
Diastase	41.0	78.0

From these results the writer would venture the statement that any material benefit, if there is such, appeared only in the case of the old seed. The seed of 1926 crop gave exactly the same percentage of germination in water as with diastase, or a 1 per cent increase over the untreated check test. It seems probable that reduction in viability is due to dimunition in quantity or loss in quality of the enzymes in the seeds and that there follows therefrom an increase in germination of old seeds thru action enzymes artificially supplied.

The effect of ether upon seed of celery. - The writer conducted a series of experiments in which new and old-crop celery seeds were etherized by placing them with 2 c.c. of liquid ether under a large bell-jar of 4 liters air space capacity for 6, 12, and 24 hours respectively previous to being placed to germinate in the usual way. For purposes of comparison duplicate sets of 3 x 100 seeds each were soaked in water at room temperature for 3 hours after which they were given similar treatment with ether for similar lengths of time and then placed immediately to germinate in the same manner as the other lot of seeds. the results of the tests are as follows:

Table VII.- Results of germination tests of old and new celery seed after treatment with ether, as compared with untreated seed.

	Dry, over ether for				Soaked in water for 3 hours then over ether for			
	6 hrs.	12 hrs.	24 hrs.	check	6 hrs.	12 hrs.	24 hrs.	check test
OLD SEED								
Test	%	%	%	%	%	%	%	%
1	89	72	53	86	0	0	0	89
2	93	94	59	93	0	0	0	68
3	75	86	75	84	0	0	0	84
Ave.	85.6	84	62.3	87.6	0	0	0	80.3
NEWLY-HARVESTED SEED								
1	38	40	34	63	2	0	0	50
2	37	45	41	57	1	0	0	49
3	37	48	35	54	0	0	0	51
Ave.	37.3	44.3	36.3	58	1	0	0	50

These results seem to show first of all that ether is not effective as a stimulant, since the check test in every case gave higher germination percentages than is shown in the untreated lots. However, the results secured from the treated lots of old seed more closely approximated those of the check test than did those of the new seed. Of the dry tests both old and new seed ran highest with the 12 hour treatment. It seemed plainly evident here that ether was detrimental to the vitality of soaked seeds of celery.

Effect of Disinfectants Upon Germination

The comparative effects of certain organic mercury compounds

(Bayer "Dust", "Semesan", and "Uspulun") more recently recommended for seed treatment were tested by the writer on lots of both old and new crop celery seed. Each lot used was first proved to be relatively free from diseased condition when cultured by the usual agar method. The method of treatment recommended with each of the compounds was followed very closely upon each of the lots to be treated immediately previous to their being placed to germinate in the usual manner. The results of these experiments in a series of preliminary tests are shown in the following table:

Table VIII. - Showing the results secured from a series of celery seed tests on old and new seed, treated with "Semesan", tested in soil.

Test Number	New Seed (Results in percentage		Old Seed	
	Untreated	Treated with "Semesan	Untreated	Treated with "Semesan"
	%			
1	65	55	47	41
2	60	51	56	49
3	64	58	35	45
4	70	57	41	46
Average	64	45	57	49

Plate 4, Fig. 1 shows the comparative behavior of Semesan treated seed to advantage.

PLATE IV

Two pots of celery plants of the same age showing the comparative behavior of old and new crop seed treated with "Semesan" dust.

Table IX. - Showing the results secured from a series of tests using treated and untreated celery seed, both old and new seed. Tests made in petri dishes at alternating temperature (20-30° C.) for 41 days.

Test No.	Treated with	New crop seed Percentage germination		Old seed Percentage germination	
	"Uspulun"	10th day	41st day	10th day	41st day
1		23	39	0	48
2		35	46	0	49
3		23	30	0	42
4		21	29	0	54
			Ave. 36		Ave. 49
	"Bayer Dust"				
1		19	31	1	43
2		24	35	0	47
3		36	62	0	35
4		57	63	0	32
			Ave. 47		Ave. 39
	"Semesan"				
1		10	13	0	43
2		24	44	0	33
3		31	42	0	37
4		38	50	0	42
			Ave. 45		Ave. 38
	Untreated				
1		51	60	0	70
2		52	62	0	50
3		54	59	0	62
4		42	47	2	53
			Ave. 57		Ave. 59

In nearly every instance the check tests (untreated seed) gave slightly higher germination results showing that unless the seed is actually diseased and thereby introducing another factor, these disinfectants proved to be a handicap. The new crop seed appeared to be less affected than did the old seed, indicating, perhaps, that the new seed was of stronger vitality and more able to withstand the deterring

PLATE V

Fig. 1. A series of tests with new crop celery seed showing the effect of treatment. Pots marked "S" are treated.

Fig. 2. A series of tests with old celery seed showing the effect of treatment with disinfectants. The pots marked "s" are those treated.

or injurious effects of the disinfectants used. In all of these trials it was noted that the compounds used had a deterrent effect which operated in the direction of retarding germination and was later noticeable by the comparative stage of development of the very young seedlings. This condition is shown in Plate 5, figs. 1 and 2, in which treated (N.S. series 1,2,3,4) new seed and old seed (O.S. series 1,2,3,4) lots of seed are compared with untreated lots.

Further experiments with disinfectants in the form of "dusts" included tests with compounds of mercuric chloride known as formula 154 x 5 and formula 100 x 3 "Bayer Dust." Counted lots of seeds from the old and new crop stock previously referred to were dusted with each of the preparations mentioned above and, according to directions, after which they were germinated in sets of 8 x 100 seeds each in light and in darkness. A check test of each was carefully observed for comparison. The results are shown in the following table.

Table X. - Showing the effect of certain dust treatments upon old and new crop celery seed germinated at alternating temperatures in light and in darkness, compared with untreated seed of the same lot.

Test No.	Seed treated with 100 x 3 "Bayer Dust"				Seed treated with 154 x 5 "Bayer Dust"				Untreated Check			
	Darkness		Light		Darkness		Light		Darkness		Light	
	Old seed %	New seed %	Old seed %	New seed %	Old seed %	New seed %	Old seed %	New seed %	Old seed %	New seed %	Old seed %	New seed %
1	86	53	89	43	86	50	86	42	67	48	86	44
2	83	50	67	58	79	48	74	40	70	35	77	56
3	84	57	88	41	85	35	76	45	69	39	89	49
4	89	59	89	58	85	34	81	53	66	40	88	41
5	88	52	79	44	87	42	71	51	74	37	66	55
6	87	48	94	42	80	34	74	47	70	41	--	43
7	82	46	71	39	84	47	84	48	73	40	81	49
8	89	49	80	35	88	42	83	40	70	38	77	48
Ave. %	86	51.7	69.5	45	84	41.5	82.1	45.5	69.8	39.7	78.6	48.1

PLATE VI

Treated and untreated lots of new crop celery seed grown in pots and showing the comparative yellow-green color of the foliage of the treated lots as compared with the darker-green color of the untreated lots.

In every case the check tests molded, this moldiness being more conspicuous on the check or untreated series germinated in darkness. It was noticeable that both old and new seed in the check tests gave a higher percentage germination in light, possibly due to the fact that mold did not form so readily in light as on moist substratum in darkness.

Because of the expected and often unexplainable variation between final germination results which do occur between series of seeds which would seem to be uniform material, the results often obtained must be considered as only indicative. It was impossible because of the long duration period of celery seed to do a sufficient number of comparative viability tests to reduce the expected average to a point where it could be measured or compared with the results of another factor such as disinfection in this case. However, out of this data which shows no great differences in terms of percentage germination it seems reasonable to conclude that this disinfectant showed its greatest merits in formula 100 x 3 since the development of fungous growth bringing about a condition commonly known as moldiness in routine laboratory practice seemed rather better under control in that series.

It was early noticed that the seedlings produced from the treated lots of both new and old seed were of a yellowish-green color in contrast to the deeper green color of the untreated lots. This marked contrast in color quite readily apparent to the naked eye is not well shown in Plate VI which shows such a set of treated and untreated plants. This difference in color became less striking as the plants from the new seed developed. However, it was noticeable thruout the entire growth of the plants from the old seed. The writer will not attempt to venture an

Fig. 1 (To the left) Plants from old seed treated.

Fig. 2 (To the right) Plants from old seed untreated

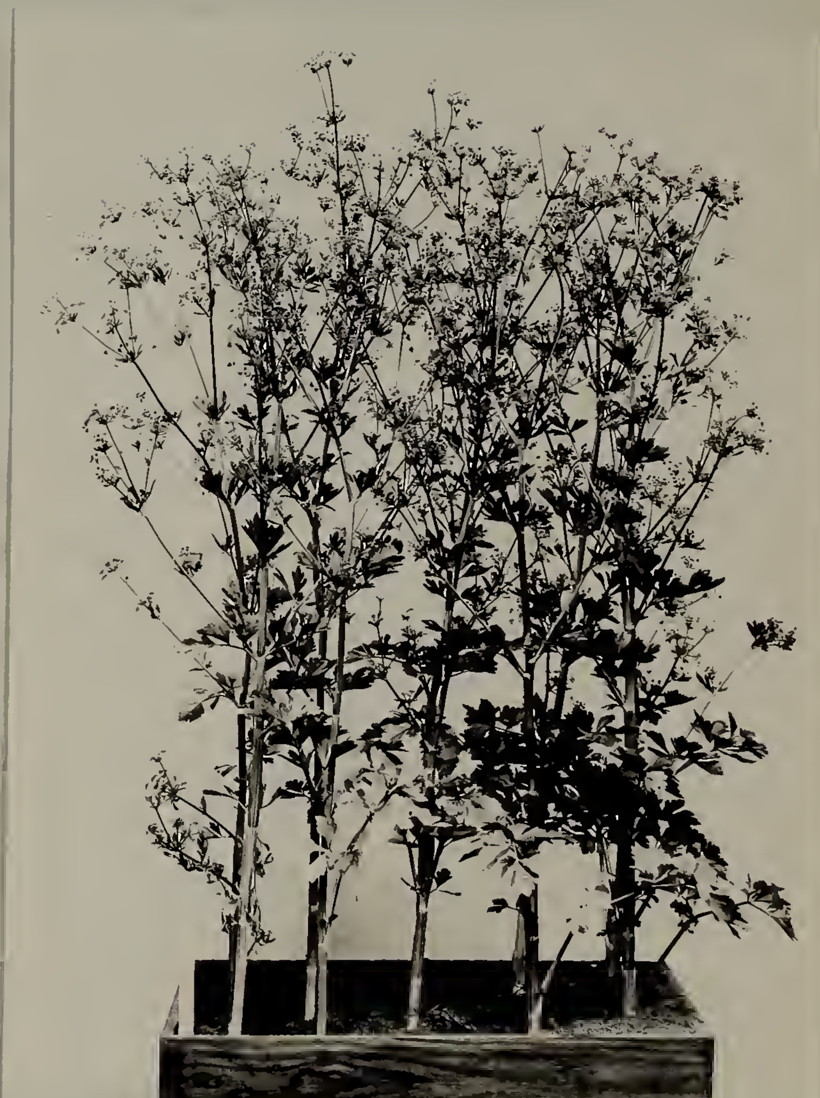

PLATE VII

Fig. 1. Showing plants produced from old celery seed treated with "Semesan" dust.

Fig. 2. Showing plants produced from old celery seed untreated.

explanation of these noted differences in color of foliage.

Another difference in behavior noted between plants from the treated and untreated lots of seed as they were permitted to mature in boxes of soil in the greenhouse was the observed tendency of both the treated old and new seed plants to produce flowers and later seed at an earlier date than did the untreated lots (Plate VII, Figs. 1 and 2), altho both lots were started at the same time and were exposed to the same conditions. As would be expected from observations from previous cultural practice with this and other plants, the plants grown from both the treated and untreated old seed fruited earlier than did those from the new seed. (Plate VIII, Figs. 1 and 2). The objectionable effect of the treatment with the mercury compounds in the direction of hastening seed formation is interpreted as synonymous to a check upon the growth of the treated plants. This is in accordance with the observations of Whipple (1917) and others that any kind of a check in the growth of celery plants at any stage tended to induce premature seed formation. Apparently, plants which Whipple subjected to cool temperature of a cold-frame produced 50 per cent seed stalks while check plants produced none. Later, Starring (1924) conducted further investigations to determine the importance of various factors that might force the development of seed stalks in celery plants. His data showed evidence that of all the factors studied cool temperature is the only one that uniformly caused celery to "go to seed."

One rather interesting and possibly significant observation made in connection with these experiments consisted of the browning of the tissue at the tips of of the growing roots of a large number of the

Fig. 1. (To the left) Plants from new seed treated. Seed produced earlier.

Fig. 2. (To
right) Plants f
new seed untrea
Produced seed m
later.

PLATE VIII

Fig. 1. Showing plants produced from new crop celery seed treated with "Semesan" dust. Seeds produced at an earlier date.

Fig. 2. Showing plants produced from new crop celery seed untreated.

Fig. 2. (To the right) Plants from new seed untreated. Produced seed much later.

PLATE VIII

Fig. 1. Showing plants produced from new crop celery seed treated with "Semesan" dust. Seeds produced at an earlier date.

Fig. 2. Showing plants produced from new crop celery seed untreated.

sprouting seeds from the untreated lots. Upon microscopic examination the tissue from these brown root tips was found to be teeming with motile bacteria. This browning of the root tips was by no means as prevalent among the treated lots and in most cases was entirely absent among them, showing that this type of disinfection may be a potent factor in the control of certain bacterial diseases affecting the young seedlings of celery. Here again, treatment with these mercuric chloride compounds also seemed to retard germination since the untreated seeds sprouted on an average of two to three days earlier than the treated lots of seed.

PRACTICAL CONSIDERATIONS

There are several important considerations or determinations to be made in order to arrive at the actual value of any parcel or stock of celery seed for planting purposes. There is perhaps no kind of seed of the vegetable seed group which gives the analyst in the seed testing laboratory more difficulty in making these several determinations than that of celery seed.

Determination of Identity

The seed analyst is often called upon to determine or establish the identity of kind, variety or strain of celery from the seed itself. Since it is impossible to do this from the appearance or characteristics of the seed material alone, it would obviously be of great value if, when making tests of the celery seed, the seed analyst could by extending the test period slightly longer determine the possible variety by the appearance and characters of the young celery seedlings produced. In an endeavor to determine varietal differences in the seedling stage, the writer planted seven flats of celery with standard varieties, including Wonderful, Emperor, Giant Pascal, and Winter Queen representing the so-called green varieties, and Easy Blanch, Golden Self-Blanch, and White Plume typical of the so-called white varieties. In each flat there was planted seed of the same variety obtained from at least two reliable sources. Altho differences could be seen between the flats of plants (as a whole) containing the green varieties as distinguished from the white, the green varieties presenting in general a sturdier, coarser leaf foliage as compared with the somewhat finer, more delicate leaf foliage of the white varieties. It seemed to be impossible to work out a definite key or scheme of differences which held consistently between the standard varieties studied. Examinations were made as to leaves in respect to their divisions, veination, markings and texture. Form of stem and development of root hairs were also observed with the result that at the end of the twelfth week no satisfactory distinction seemed apparent other than that mentioned of the generally more delicate, finer-leaved habit of the blanching types. There are those gardeners and plant propagators who claim to be able to distinguish the Golden Self-Blanch celery in the seedling stage, and also the Curly-Leaf Easy Blanch with its distinctive characteristics. Work (1925) states that in mature plants varieties of celery may be partially identified on the basis of differences in the cross sections of leaf petioles. Cross sections of large petioles proved of considerable value. The form was recorded by slicing the petioles in cross section at three different points and using the cut surfaces to make an ink impression. They range widely from the thick type of Emperor to the thin form of White Plume. The writer abandoned this study as falling without the province of possibilities of the routine seed testing work since it more properly became a matter of plant propagation in determining identity of strain, variety or sort.

Purity Analysis of Celery Seed

The mechanical purity of a stock of celery seed, that is, its freedom from inert matter, weed seeds, and seeds of other crop plants is of particular importance because of the relatively high price of this commodity. In arriving at this determination the question of what constitutes a "pure seed" or "pure Seed" should be first considered. According to the Danish Rules (Rules for testing which accompanied the International Referee Samples of 1926) for analyzing celery seed whenever two badly shriveled seeds are found adherent to each other, both are to be counted as inert matter: in case of one plump seed adherent to its companion shriveled and immature seed, the smaller portion is to be separated and discarded from the pure seed separation. It seems to be the custom in European laboratories generally in making purity analyses to regard all dead, brown, shriveled or shrunken immature seeds as non-viable and hence as inert matter. This method or practice does not seem to be the commonly accepted one in American seed testing laboratories, it being held that every seed of the kind being examined is a pure seed regardless of its stage of development or condition and that to remove such seed at the time of making the purity separation is essentially the same as attempting to measure the viability of the product when making the purity analysis or determination. According to the practice in this country, and the one which the writer has uniformly followed, only pieces of seed which are broken and thereby reduced to portions less than one-half size are taken out as inert matter, a practice which all analysts alike may follow with safety. All immature or shriveled seeds are weighed with the plump, well-filled seeds, and from this whole sets of 100 seeds each are taken or counted indiscriminately for viability tests. With a sensitive seed like celery seed the writer feels that the very minimum of 4 x 100 seeds should be used in every case to avoid wide variations or unreliable results. At this point it seems best to point out that because of the fact that these fruits or seeds are borne in pairs (Plate I, figs. 1, 4, 6) often adhering in the commercial seed there is a disadvantage and possible source of error not recognized in measuring viability in using double seeds for germination tests since a common occurrence when such "double-seeds" are used and not separated is that of the immediate germination of one seed of the pair which with the emergence of the radicle is borne up on the developing cotyledons carrying with it and away from the moist substratum the closely adhering companion seed. In this manner the one ungerminated seed is deprived of conditions necessary for germination, andthus in failing to sprout may be counted as non-viable. Where a large number of such "double-seeds" are used in a series of tests it may readily be seen that unfair judgments may be passed on the germinative ability of a particular sample. In continuation of this matter of purity measurement then this method as outlined as followed in American laboratories seems more fair in measuring both the purity and viability of a particular sample or parcel of seed.

Commercial samples of celery seed frequently show a blending with the fruits of mineral matter, particularly earth, vegetable matter, pieces of stems and leaves, weed seeds, and caryopses of grasses from plants growing with the cultivated celery. Because of the high market value of celery seed one often finds a number of fraudulent impurities, particularly in the imported French seed. Broken and discolored pieces of almond shell are often found with an excess of earth or sand left in after harvesting, the resemblance of which is so close to the size and shape of seeds themselves that they may be present in the proportion of 10 to 15 per cent without being easily detectable by superficial examination. The light weight of the seed of course favors this falsification. Detailed purity analyses were recently made by the writer on 20 samples of celery seed. These samples consisted of the sealed packets from the commission boxes for sale upon the open market and representing the stock vended by a number of different seedsmen. Exact weight samples were taken in each case, its size depending upon the amount of seed in the packet, which ranged from one to two and one-half grams. The average purity as determined for the packets was 98.07 per cent. The weed seeds most commonly found were Amarathus graecizans and other Amarathus spp., Chenopodium album, Ambrosia artemissifolia, Daucus carota, Rumex spp., and particularly Rumex acetosella. It is the usual experience and finding that the mechanical purity and possibly the viability of commercial bulk celery seed sold to market or truck gardeners is much superior in quality to that sold in closed packets.

Testing for Viability Methods

In the germination testing of celery seed various substrata, including sterile filter paper, tissue toweling, sterile blotters, plaster blocks, sterile gauze, sand, soil, and even water alone may be used. The "Rules for Seed Testing" (1927) suggest that celery seed be germinated on top of blotters. This is probably the method most commonly used in the majority of seed-testing laboratories. Any paper material, providing, however, it is folded so as to furnish sufficient absorbent substratum for the seeds may be used. Harrington (1923) in his investigations with celery seed placed the seeds for germination on the surface of blotters folded four times. Damp filtering paper seems to have been most usually employed as substratum in most of the experiments performed by European workers referred to in this discussion. The Holland seed testing station (Methods for the Testing of Seeds at the Government's Seed Testing Station at Wageningen) recommends filter paper with the Jacobsen germination apparatus, diffusely lighted (not direct light) for the germination of celery seed.

In experimenting with various substrata the writer used seed from special lots of new and old-crop stock which appeared to be nearly equal in viability, the maximum percentage obtained from each lot when germinated under most favorable conditions being 68 and 66 per cent respectively. In each case the substratum used was first thoroly soaked and then allowed to drain for one minute before the seeds were placed thereon. The average results secured from each of the lots for the tests under the various conditions are as follows:

	New crop seed	Old crop seed
Percentage germination when tested on:		
Blue seed germination blotters	66	61
Sterile filter paper	66.5	66
Sterile gauze	58	52
Plaster Paris blocks	45.5	38
Sand	64	57
Tissue paper toweling	60.5	65.5

These results seem to point in the direction of favoring the use of blotters and filter paper as most favorable substrata, and of these two, filter paper is perhaps to be preferred since there is usually less tendency to moldiness.

The writer also experimented with several kinds of germination apparatus, including bell-jars, closed chambers, daylight germinators, petri dishes, unglazed porcelain dishes, tanks and soil. Of these the bell-jar or candle-wick method employing the tumbler, candle-wick, candle-drip (bobeche), and cover glass seems most deserving of recommendation, with merits based both upon convenience and also surety in providing a constant and uniform supply of moisture to the seeds, the latter being a factor in respect to which many of the other pieces of apparatus are found lacking or erratic. The often recommended petri-dish method, for example, is perhaps one of the least satisfactory in this regard since its shallow depth permits rapid drying out of the substratum below the seeds. Attention should be invited to the relative merits of the daylight germinator as compared with the commonly used dark or closed type of germinator for testing celery seed. It has been shown that light and temperature alternation are essential factors to be provided in successfully germinating celery seed. The writer has found a most satisfactory means of testing celery seed to be that of keeping the set-ups (either in Bell-jars or on blotters) in a daylight germinator at 30° C. during six hours of the day and transferring them to another chamber maintained at 20° C. for the remaining 18 hours of the day. Thus the celery seed is furnished optimum temperature conditions in the presence of light, which acts favorably both as a stimulant and as a deterrent to the growth of molds.

Sand tests proved more tardy in response than did those in bell-jars and chamber. It was observed also that seedlings from old seed germinated in sand showed evidence of root-rot, in some instances the cotyledons being entirely dismembered from the primary root. This may have been due to moisture conditions of the sand, but since both lots received the same amount of moisture during the test and this condition appeared only among the plants grown from old seed, it is perhaps further evidence of the superior vigor of the plants from the newer seed.

Duration of Tests

Apparently seed testing stations disagree on the time interval required for the complete germination of celery seed. According to a table published by a seed trade reporting bureau and purported to be based upon work done by the Bureau of Plant Industry, United States Department of Agriculture, fourteen days are sufficient for germination test, the first or preliminary count to be made on the sixth day. The Holland Station, in their rules as previously referred to, advocates twelve to eighteen days. The American official rules for seed testing, also referred to above, carry the recommendation that the preliminary count of sprouts be made on the tenth day and the final count on the twenty-first day. The Danish Station considers celery tests completed after twenty-five days' duration, with the preliminary count to be made on the eighth day. In Italy, information gained by the writer showed that celery-seed tests were usually continued a month in germination.

Observations made upon numerous tests coupled with experimental work done by the writer lead to the conclusion that all celery seed viability tests should be extended thru a period of at least twenty-one days, and in cases of old seed which is weak and consequently often slow in its response, probably a duration period of at least twenty-eight days is necessary. By extending blotter tests of old seed, the writer has obtained as high as an eight per cent increase in germination even after twenty-eight days. Sand tests are admittedly more tardy than chamber tests and hence sometimes require special consideration in the matter of deciding when the test should be terminated. The Canadian Experimental Farm Report (1891) describes a varietal test in which thirty kinds of celery were included. The seed sown March 31st in sand germinated in thirty days. This should probably be accepted as the average time period to be allowed for the germination of strong, normal seed in sand. A striking instance showing the time requirement of very weak celery seed is demonstrated by the writer's experience with one set of 6 x 100 seeds which on the twenty-eighth day gave an average of 16.2 per cent germination. The final count made on the forty-first day on this series, however, was 57.2 per cent, or an increase of 41 per cent which had sprouted after the prescribed period of twenty-one or twenty-eight days when under routine practice the test would have been discontinued. Attention should be called to the fact, as stated elsewhere in this paper, that celery seed germinated at low constant temperature much more slowly than at alternating temperatures, and the same is true according to Morinaga (1925) of celery seed germinated under water; altho this of course is not the usual practice. It may be said of the water method that even if results in percentages were just as satisfactory, the greater difficulties involved in oounting and removing the sprouts would render the method prohibitive.

The method of quickly measuring the viability of seeds by catalase activity has proved quite successful in several instances. Davis (1924) seems to be the only investigator who has applied this principle to celery seed, since in an unpublished paper given before the Physiological Section of the Botanical Society of America he stated that celery seeds show a much greater total use in catalase activity at alternating temperatures previous to germination than is even shown at corresponding constant temperatures. He assumed the reason for this to be that the alternating temperatures are modifying the growth behavior of the embryos themselves. Morinaga (1925) also found that alternating temperatures effect the embryos of Bermuda grass in a similar way.

In the study of the behavior of celery seed placed to germinate in water it was found that a few investigators had previously included celery seed in their study. Morinaga (1925) found as a result of his extensive work with the germination of seeds under water that out of 78 genera of 24 families of plants, seeds of 43 genera germinated in water, and even some of the 35 genera which did not germinate under the conditions of the experiment germinated if fewer seeds were placed in the flask of water. In his experiments celery seed showed good germination under water, the mean of duplicated tests in water being 88 per cent germination as compared with 92 per cent germination in petri dishes. Altho certain investigators, Hartleb and Stutzer (1897) and Kraus (1901) had held that seeds were unable to germinate in boiled water on account of the absence of oxygen, Morinaga demonstrated that out of 21 kinds 20 germinated well in distilled water even when the distilled water was covered with paraffin oil. The conditions of the experiment were as follows: Florence flasks of 100 c.c. capacity were nearly filled with boiled distilled water and cooled quickly in ice water. As soon as the water was cool enough, seeds were put in and sealed with the paraffin oil. These flasks were placed in the greenhouse. When the seedlings that germinated in the flask became green, records were taken and the flask was discarded because oxygen could be liberated inside the flask by photosynthesis as soon as chlorophyll was formed. This experiment, therefore, does not show any final percentage of germination, but proves the contention of the investigator that seeds can germinate in boiled water free of oxygen. The twenty-one kinds of seeds which he chose for the experiment germinated well in water, and it was found that the seeds of all species except alfalfa gave fair or good germination. These results did not agree with those of previous workers mentioned above, but, as pointed out by Morinaga, the discrepancy may have been due to a difference in the methods of sealing, to a difference in species, or to a more favorable alternation of temperature. It is interesting to note that celery seed obtained a germination of 52.5 per cent in his experiments. Bermuda grass, chamomile, and night-shade seeds gave highest percentages in germination under the conditions described, and this investigator stated that the ability to germinate under water seemed more marked among small seeds but was apparently not related to phylogeny or to kinds of reserve materials in the seeds. He noted , especially with regard to the behavior of celery seed, that it germinated more slowly in water, but showed practically no difference between water and filter paper in final percentages of germination. In this connection, however, he pointed out that there was a difference in temperature which maintained in the two methods, the maximum temperature being higher on filter paper than that in water.

The writer made germination tests of freshly-harvested celery seed in water, finding the behavior of the seeds similar to that described by Morinaga as discussed above. On August 27, the day collected, the seeds were arranged in sets of 4 x 100, one set being germinated in bell-jars with light, one in bell-jars with darkness, and one set in water. The first count was made September 7 when the bell-jars in light showed a germination of 80.5 per cent, the bell-jar in darkness 75.2 per cent, while in water only 14 per cent of the seeds had sprouted. Evidently both of the bell-jar series had continued to completion on the 11th day since not more sprouts appeared. On the other hand, the seeds in water continued to germinate slowly and intermittently, forty days after starting the test, a final count gave a germination of 76.5 per cent. These results substantiated Morinaga's statement that celery seed will attain full germination value in water provided sufficient time is allowed.

Unit Weight of Celery Seed

The weight per unit of seeds or the weight of 1000 seeds is of particular importance. By the seed analyst this determination of unit weight is made on the basis of the weight of 1000 pure seeds of the sample. Often comparative values of two lots of seed of celery can be judged, other conditions being equal, on the basis of the weight per 1000 seeds. The weight of the individual seed has much to do with its vitality. This has been amply demonstrated at the Massachusetts Experiment Station where it was found that celery seed, after being blown and separated from approximately 15 per cent of chaff and light seed, gave a difference in percentage of germination between the heavy and discarded seeds of 32 per cent, while there was reported a gain of 68 per cent in germination in favor of the heavy seed.

In this connection the writer made determinations of the weight upon a number of samples of six of the standard celery seed varieties. Lots of seed of six standard commercial varieties were chosen for examination as to weight per 1000 seeds. Three parcels of commercial seed which had been treated identically as to recleaning were used as a basis for determining weight. The average weight per 1000 counted seeds of the six varieties are as follows:

Variety	Weight in grams of 1000 seeds
Golden Self-Blanching	.302
Giant Pascal	.331
Wonderful	.368
French Success	.414
Winter Queen	.496
White Plume	.534

The usual statement given in gardeners' handbooks and cultural guides is that one ounce of celery seed contains between 60,000 and 70,000 seeds. The observations made in this study lead to the conclusion that when considering or comparing 1000-seed weights in the case of celery it is necessary to recognize the variety characteristic and also that these weights may vary from season to season, dependent upon conditions under which the seed was produced.

Seed-Bourne Celery Diseases

There seems to be but two generally recognized seed-borne plant parasites of celery seed, namely, <u>Phoma apiicola</u> Kleb., the causal organism of Phoma root-rot of celery and Septoria apii (Br. and Cav.) Rostrup, the cause of the well known late-blight of celery. Since the fungus which causes the Phoma root-rot does not often grow in or on the seed itself, and then only in the form of external or internal mycelium, it is not readily recognized by the seed analyst when making tests or working with that material. However, from the seed standpoint, the seed specialist should be concerned in every effort being made to secure clean seed from disease-free fields. The other, and perhaps much more common seed-borne celery disease, and the one responsible for the destructive late-blight of celery is often very easily detected on the seeds. This fungus, in addition to the other over-wintering forms, may be found as mycelium among the cells of the seed, the hyphae evidently not penetrating deeply to the embryo but more easily detected in the form of dark-brown or black pycnidia or fruiting bodies breaking thru the seed coat. A binocular microscope is very useful in detecting these tell-tale pycnidia or fruiting bodies upon diseased seed. Quite frequently lots of low quality diseased seed will show numerous seeds so diseased when carefully examined under sufficient magnification. Experiments have demonstrated that the fungus within the seed tissue , as well as the external form, dies within a period of two to three years; therefore seed which has aged for three or four years, if still strongly viable, is quite satisfactory for seeding purposes without the usual recommended seed treatments and their attendant seed treatment injury. It is highly advisable when setting up celery seed germination tests to guard against subjecting either the seed or the apparatus used to contamination thru dust or dirt during the counting and spreading out of the seeds. Only sterile blotters and filter papers should be used, and these should be carefully protected and covered immediately after moistening. Contamination at this time means the later formation of mold which will certainly handicap, if not entirely check, germination in the case of these very sensitive and slowly germinating seeds.

SUMMARY

1. Celery is one of the oldest of vegetables, and for years existed only in the wild state. It has developed remarkably with cultivation and is now one of the most valuable market garden crops.

2. Concerning longevity and maturity of the seed it may be said that five-year-old celery seed may germinate as high as ninety-one per cent providing it has been stored under optimum conditions of favorable storage. In practice it is probably best to sow at least two-year-old seed since seed-borne fungi are found to be incapable of serious injury after two years, and the seed on the other hand may be expected to retain its vitality for an average period of at least three years. Unripened celery seed, if harvested very green, will not germinate. Seed that is only slightly immature may sometimes be forced to germinate if chilled with ice for several days previous to being brought into light and heat.

3. Experimental data on the whole seems to show but little influence of light on the germination of both newly-harvested and old celery seed. Light is an important factor in the control of mold formation during germination testing, and in weak lots it is therefore probable that higher percentages are to be expected from seeds germinated under light conditions. Red light seems to influence old seed by furthering its germination, but does not appear to prove of advantage in the case of new seed. Results of experiments performed by the writer seem to indicate that both old and new crop celery seed

may be mildly stimulated in germination thru the use of ultra-violet rays. Altho violet rays seem to induce somewhat earlier germination of the celery seed, it is evident that seeds thus forced do not emerge as strong, healthy sprouts. On the other hand, molding is slightly controlled by use of violet rays.

4. Temperature is an extremely potent factor in the successful germination of celery seed. An alternation of temperature from 10° to 25° C. gives maximum results. Results in germination secured at a constant 15° C. temperature closely approximate those obtained with temperature alternation, but seeds are considerably slower in responding at low constant temperature. On the other hand, a constant temperature of 30° C. appears to have a tendency to throw the seed into a semi-dormant state and it is then difficult to attain satisfactory germination at high constant temperatures.

5. Disinfectants of a mercuric chloride or organic mercury nature such as were used by the writer proved to be a handicap unless the seed proved to be actually diseased. New seed showed detrimental effects to a less extent than did the old seed. Injury in the case of old seed manifested itself in a yellowish-green coloration of the foliage. Mercuric chloride compounds tend, generally, to retard germination.

6. Enzymes and stimulants in case of vigorous seed proved of negligible effect, but with old seed which is weak and low in vitality, enzyme treatment is beneficial. Similarly, ether proved to be a mild stimulant with old seed, but less noticeable with new seed having strong vitality. Neither old or new seed is able to withstand the

effect of soaking in water previous to ether exposure.

7. It is impossible to determine varieties of celery from an examination of the seed. It is also exceedingly difficult to detect varietal differences at the seedling stage, altho when greenhouse flats containing different varieties in the seedling stage are viewed together, the green varieties may usually be distinguished from the so-called white varieties by the coarser leaf characters of the former.

8. The average purity of the co-called commission-box sealed packets of celery seed found upon the open markets was found to be approximately 98 per cent. The mechanical purity, and probably also the viability of the commercial bulk celery seeds sold to truck gardeners is higher than that from the ordinary commission-box sealed packet stock. Because of the relatively high price per pound of celery seed there is a tendency in some cases to adulterate the seed with materials designed to give weight and to escape detection by the casual observer.

9. In making viability tests of celery seed daylight germinators with blotters are to be recommended. The bell-jar (BJ) method with filter paper as substratum is also very satisfactory. Tests in sand or soil are slower than blotter or bell-jar tests. Celery seed may be germinated in water, altho considerable more time must be allowed for the completion of such tests. Experience points to the desirability of continuing germination tests of celery seed germinated by the usual method of bell-jar or blotters at least

twenty-one days. There is a disadvantage in using "double-seeds" for germination in that difference in time of sprouting of the two seeds brought about by physical behavior results in the ungerminated seed being lifted away from the moist substratum. Such seeds should be separated.

10. When considering or comparing 1000 seed weights in the case of celery, varieties should be recognized as well as the fact that such seed weights may vary from year to year, depending upon the conditions under which the seed is grown. The weight per unit or the weight of 1000 seeds is important, and in case of celery seed the weight of the individual seed has much to do with its vitality. The weight of 1000 celery seeds, the basis usually considered by seed analysts, varies from 0.302 grams to 0.534 grams, depending upon the variety. In common usage it is considered that there are from 60,000 to 70,000 celery seeds per ounce of weight.

11. Only one seed-borne plant parasite, namely the causal organism of the late-blight of celery (Septoria apii, (Br. and Cav.) Rostrup), can be detected on the seed itself. It is observed in the form of brownish-black pycnidia or fruiting bodies upon the seed coats.

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