VERNALIZATION

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By

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CHESTER E. ROOT, JR.

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THE PROBLEM

Agricultural crops which are ordinarily planted in the fall of the year will not produce seed as a rule during the first season if planted in the spring of the year but will continue prostrate vegetative growth during the first season and produce seed during the next year. If the seed of these fall-sown crops is germinated and subjected to a period of cold treatment prior to planting they produce seed the first year instead of remaining in the vegetative stage.

The so-called sub-tropical plants, or short-day plants such as corn, sorghum, millet and soybeans will have an accelerated vegetative period if germinated and kept in darkness for a short period at relatively high temperatures before planting. Most of the work in the past has been with cold temperature pre-treatment prior to planting and the warm temperature pre-treatment has received very little attention.

The term vernalization is used to designate the pre-treatment of seed which brings about an accelerated or shortened vegetative period of the plant. Vernalization seems to be the accepted term in the United States; however, some authors use iarovization or iarovizatsii, which McKinney and Sando (8) state means "Springization" in Russian. Other terms used are yarovization, vernalization, and jarovization. All of these terms mean seed pre-treatment before planting which affects the vegetative growth of the plant, therefore the term vernalization was used in this work to avoid confusion in the use of terms.

Most all of the outstanding work on vernalization has been done in Russia. Hudson (4) states that in special circumstances such as exist in large areas of the north of Russia, where winter sowing is not possible, this vernalization treatment makes it possible to grow winter varieties by sowing them after treatment in the spring, and so permits the growing of desirable varieties of cereals that have so far been quite ruled out for these areas.

Thus, at Hibney in the Arctic Circle, many southern varieties of wheat and even winter and semi-winter varieties of barley that normally do not even come into ear there, have been brought to maturity by the application of vernalization. In experiments on the whole world collection of wheat,vernalization accelerated ear development by 2 to 4 days in the majority of varieties, but in 12 per cent of the varieties an acceleration of 5 to 10 days was obtained and more than 10 days in 17 per cent of the varieties tested. Similarly with barley, after vernalization all the 1505 varieties came into ear, whereas without treatment only 665 of these varieties eared and even these were very irregular, whereas the rest formed no ears at all.

Again in the southern wheat growing areas of the U.S.S.R., such as the Ukrainian Steppes, certain desirable imported wheat varieties are excluded from cultivation because they either fail to ear altogether or else reach maturity too late and are damaged by drought. The earlier maturity induced by vernalization enables some of these varieties to mature before the drought sets in and so escape this damage entirely. In many areas where wheat growing is precarious, the slight acceleration in maturity induced even in the local wheats by vernalization insures a more certain yield, and vernalization is now practiced over thousands of acres of such country in the Soviet Union, and its more extensive application is constantly being recommended.

This work was undertaken for the purpose of determining the value of vernalization to Oklahoma agriculture. If the method is of value to farmers in other countries, there is reason to believe that it may prove to be of value to agriculture in this country. The practical application to the average farm is worth investigating.

1 2 3 4 5 6

Illustration 1. Turkey red wheat showing the effect of vernalization. The seed was germinated and subjected to a period of cold treatment prior to planting March 17, 1937. Note that Row No. 1, which received no treatment remained in the vegetative stage and did not produce heads. Row No. 1 will produce seed in the summer of 1938. Rows No. 2, 3, 4, 5, and 6 came into head from 62 to 74 days after making their first appearance above ground, depending on the length of the cold treatment.

WORK OF PREVIOUS INVESTIGATORS

Blackman (1) in discussing vernalization, states that Gassner in 1918 was the first to investigate vernalization in Germany. Gassner found that it is a well-known fact that winter varieties of wheat and rye, if sown in the spring, will not produce ears during that season or, if ears are produced, no satisfactory crop can be harvested. Spring cereals, however, do not have this disability. Gassner conceived the idea that delay in flowering of spring-sown winter wheat might be due to the lack of exposure to chilling which the winter sowing insures. Accordingly, he exposed seedling plants of winter wheat for thirty days to a temperature a little above freezing point, with the result that they flowered about the same time as the spring varieties.

McKinney and Sando (8) also discussed methods of vernalization as used by the Russians. Lysinko (6) worked out a very simple method of vernalization which may be used on the average farm. The grain is spread out in a layer from six to seven inches deep on the floor. Water, at the rate of about one-third of the weight of the seed, is sprinkled over the seed, the water being applied in thirds with intervals of eight hours between the applications. The final moisture content of the seed should be 50 to 55 per cent. The seed is allowed to germinate at 50 to 60^{0} F. for about 24 hours and is shoveled over three or four times during the process. The germinated seed is held at 32 to 34.2 degrees F. for 40 to 55 days and stirred many times during the process of chilling. The low temperature of winter is used for chilling the grain, and this is regulated by opening and closing the windows of the building. The amount of germination is accelerated or retarded by controlling the amount of moisture added to the seed or by adding salt solutions, which retard germination. In spring wheats, especially durums, the moisture content is raised only to 45 to 50 per cent. The germinated seed is held at 33.8 to 41 degrees F.

Lysinko also states that sexual reproduction is accelerated in so-called short-day plants such as corn, millet, sudan grass, sorghum and soybeans, by germinating the seed slowly in uninterrupted darkness at moderately high temperatures for suitable periods. The time of exposure at the suitable temperature is calculated from the first signs of germination. Different varieties of the same species sometimes require different treatments for the best results. Lysinko emphasizes the importance of darkness. He considers that short-day plants do not require an alteration of definite periods of light and darkness but rather a certain total amount of light and a certain total amount of darkness, and he takes the view that the cause of the late maturing of the short-day plants in northern regions is not the long day but the short night.

WATER CONTENT OF SEED, TEMPERATURE, AND TIME OF EXPOSURE IN DARKNESS
NECESSARY TO STIMULATE EARLY SEXUAL REPRODUCTION IN CERTAIN PLANTS HAVING THE SPRING GROWTH HABIT.

Crop	% of Water by Wt. in Seed	Temp. of Seed (F.) during Exposure	Days of Exposure
Millet	30%	68 to 86	10 to 15
Sudan Grass	26%	77 to 86	5
Sorghum	26%	77 to 86	8 to 10
Soybeans	75%	68 to 77	10 to 15

Lojkin (5), one of the most outstanding workers in the United States on vernalization states that both temperatures and light are important factors influencing the transition of plants from the vegetative to the reproductive stage. The heading of winter cereals depends upon the date of sowing, the climate, and the variety used. For each variety of winter cereal, there is a definite or critical date of planting which depends upon climatic factors. If sown before this critical date, the plants of any winter variety will head during the first summer. If sown after this critical date, the plants continue prostrate vegetative growth during the summer and head during the next year.

Lojkin lists the following results from experiments on vernalization.

1. Temperatures of one to three degrees C. were satisfactory in producing yarovization of Turkey Red and Leaks Prolific Wheat. A temperature above three degrees C. produced molding and excessive germination.

2. Yarovization did not proceed at freezing temperatures, although freezing during the process did not kill the seeds.

3. Seeds which germinated actively in refrigerator treatment produced plants of a higher degree of yarovization.

4. Yarovization proceeded at any moisture content which was suitable for sustaining the seeds in an active stage of germination. For the varieties used, moistures of 50 to 70 per cent maintained continuously were found adequate. An initial moisture of not less than 60 per cent was required if the moisture content of the seed was not further adjusted during the cold treatment.

5. Drying the yarovized seeds and exposing them to warm temperatures decreased or nullified the yarovization already produced.

6. The duration of the low temperature treatments necessary to produce yarovization was found to be nine to ten weeks for Turkey Red, Leaks Prolific, and Blackhull Wheat, and about eight weeks for Ibid, Wisconsin Pedigree No. 2 and Tenmarq. These varieties required a shorter treatment if sown early and exposed to the natural low temperatures of spring.

7. Prolonged temperature treatments did not nullify the yarovization properties.

8. With a long day and warm temperature, yarovized seed sown in May headed in 56 days while that sown in early spring headed in approximately eighty days.

9. Turkey Red and Leaks Prolific Wheat not yarovized but grown continuously at a temperature of 16 to 22 degrees C.

and a day length of 15 to 16 hours headed in about 150 days after sowing. In the completely yarovized plant, the total length of time from the beginning of the cold treatment to the end of the vegetative period was equal to 110 to 120 days under most favorable conditions.

10. Yarovization treatment produced a decrease in the percentage of germination of wheat sown in the field.

11. Low temperature treatments did not shorten the vegetative period of the spring cereals: Blue stem wheat and Clydesdale oats.

Borden (6) ran yarovization experiments on the world collection of barleys whichconsisted of 50 strains and four botanical species. Out of the fifty strains of treated barleys, seven produced typical yarovization effect, or "winter type response" (full heading in experiment and grass clusters in check). Ten showed acceleration of heading and ripening or "winter spring" type response, and two by slight acceleration of heading or "spring winter" type response. Thirteen strains did not respond to the treatment used, remained in the grass cluster stage both in experiments and checks, and were classed as "stubborn winter types". Nine varieties produced heads in both experiments and checks, or "spring type response". The yarovization effect among barleys is more diversified than in the case of winter oats.

Purvis (11) worked with rye to determine the influence of temperature on the subsequent development of the plant in relation to the effect of length of day.

Purvis came to the following conclusions concerning the vernalization of rye.

1. Germination at temperatures a little above freezing point substantially hastens the flowering of plants sown in the spring. When, however, the plants are exposed to the short days of winter or to a day-length artificially shortened to ten hours, the hastening effect is not manifested.

2. Investigation of early stages in flower formation show that after germination at 1 degree C., artificially shortened days retard flower differentiation. After germination at 18 degrees C., however, short days hasten it to a small extent, although in this case long days are necessary to complete the process of flowering.

3. Experiments with spring rye (variety Petkus) show that temperature at germination has no effect on the rate of flower production, which is even more rapid than that of the winter rye germinated at 1 degree C. Short days inhibit flowering, and it may be said that summer rye, and winter rye germinated at 1 degree C. react in the same way to length of day as do typical long-day plants.

4. Reduction of nitrogen supply has no effect on flowering under any day-length, but reduced vegetative growth.

5. Reduction of potash supply had no effect on flowering after germination at 1 degree C. but appeared slightly to delay flower differentiation after germination at 18 degrees C.

6. An estimation was made of the concentration of sugars and of nitrogen in leaves of the different series of plants. There is, however, no evidence that such differences

as were observed bear a causal relationship to flowering.

7. In assigning a plant to its photoperiodic category, the time of formation of flower primordia should be considered rather than the time of emergence of the inflorescence.

8. In winter rye, the differentiation of flower primordia is subject to an interaction between day-length and the temperature during germination, which factors determine both the minimal number of leaves formed before differentiation of flower primordia begins, and the rate of growth of the meristematic tissue.

9. In spring rye, there is no "temperature after-effect" but short days retard the differentiation of flower primordia. When this differentiation has begun, further development is always hastened by long days. Therefore, if ear emergence is the criteron of flowering, rye is in all cases a long-day plant, but when differentiation of flower primordia is considered, it can be said that winter rye, after germination at high temperatures, is a "short-day" plant.

Gfeller, Derick and Frazer(3) germinated Turkey and Early Blackhull Wheat and held them at 35 degrees F. for 60, 30, 15, 7 days. Just prior to planting each lot was divided into three parts. One part was frozen at 28 degrees F. for three hours. The second lot was frozen at -40 degrees F. for an hour, and the third part was planted without further treatment. All seed which had been held at 35 degrees F. for periods of 60 and 30 days, irrespective of any additional treatment prior to planting, headed at approximately the same time as spring wheat. The wheat in the other plots gave no evidence of heading long after the headed wheat had matured. The lots which were severely frozen prior to planting gave a poor stand and headed later. For eleven years Turkey Wheat was seeded in the spring. One planting was made at the first of March, the second planting being made about the last of March. The March 1 planting yielded on an average eight bushels per acre while the planting which was made about the last of March has been a complete failure.

A group experiment was carried out at various stations in the winter wheat belt by McKinney, Sando, Swanson, Hubbard, Smith, Suneson and Sutherland (9) for the purpose of working out a practical farm vernalization procedure and to determine the value of the cold treatment for winter and spring wheat. They found that storing the germinated wheat out of doors under straw or in open sheds was very unsatisfactory as the temperature either went too high and caused molding or over-germination, or it went too low and injured the seed. The seed which was chilled in the refrigerator at 32.8 degrees C. for 65 days gave the earliest heading. Next in order was the series chilled for 50 days, followed by that chilled for 35 days. These workers conclude that from a technical standpoint further experiments are necessary to determine the commercial value of vernalization in the United States. From information now available, the method does not indicate very great possibilities in commercial wheat production.

There are available too many standard varieties well adapted that there seems to be no need for vernalization of spring wheat. Where excessive rainfall or drought has prevented planting, it might be useful in the winter wheat belt, but for use as a catch crop from winter killing or blowing out it would not be practical as the loss is usually not determined until it is too late to vernalize the seed. For the rapid increase of progenics and selections in winter wheat, chilling methods can be used to advantage.

Martin (7) states that no direct evidence regarding the practical value of low temperature yarovization of winter wheat in the United States is available. In 62 field experiments in seven states, winter wheat coming up in the spring after having been "naturally iarovized" by late fall or winter seedling yielded on an average of 1.5 bushels per acre less than spring wheat and 8.4 bushels less than early fall sown winter wheat. Iarovized sorghum seed (treated at high temperatures as recommended for crops of this type) failed to produce earlier maturity or better growth than untreated seed of the same 41 varieties in experiments conducted in 1933. The germination of the seed in most of the varieties was either greatly reduced or entirely destroyed by the treatment. Other spring grains showed little or no effect of iarovization except in reduced germination.

No satisfactory method of iarovization under farm conditions has yet been devised. The obvious difficulties of temperature control, such as excessive sprouting, moldy seed, low germination, and drying the seed, or seedling moist, partly germinated seed, are ample evidence that iarovization is not of immediate value to the practical farmer.

Murneek (10) states that in studying literature dealing with photoperiodism and vernalization, one frequently encounters confusion in respect to the use of the appropriate terminology. Naturally, this may be due to misinterpretation of experimental work and misunderstanding of results obtained.

With the object of clarifying to some extent the existing situation, the following list of definitions is presented:

Photoperiod. Length of daily exposure to light. (Garner and Allard)

Photoperiodism. Response of plants to photoperiod (Garner and Allard).

Long-day plants. Species, varieties and strains in which the flowering period is accelerated by a relative long daily exposure to light, usually more than 12 to 14 hours. (Garner and Allard).

Short-day plants. The opposite.

Photoperiodic induction. The carry-over effect of a photoperiod conducive to sexual reproduction to one opposite to it and vice versa. Also the transfer of photoperiodic stimulation to a non-treated part of the same plant. (Lubimenko and Sceglova)

Photoperiodic after-effect. The same as photoperiodic induction. (Maximov). Plants may exhibit also "temperature" and possibly other "after-effects".

Thermoperiodic adaptation. The adaptation of plants, in their native or artificial habitat, to periodic changes in temperature (Lubimenko).

Photoperiodic inhibition. Inhibition retardation of growth, primarily of main axis, by certain photoperiods (Murneek).

Jarovization. A preliminary treatment of seeds (with cold, heat, darkness, light, etc.) to induce early reproduction in crop plants (Lysenko).

Vernalization. English equivalent of the word jarovization (Whyte and Hudson).

Physiological predetermination. Effect from treatment of condition of seed which influences the future development of the plant (Kidd and West).

Phasic development. A theory that in their development plants pass through definite successive stages or phases (Lysinko).

MATERIAL AND METHOD

The seeds employed in this study were grown on the Oklahoma Agricultural and Mechanical College Agronomy Farm, Stillwater, Oklahoma during 1936.

The crop seeds used were as follows:

Turkey wheat (Triticum vulgare)

Fulcaster wheat (Triticum vulgare)

Durum wheat (Triticum vulgare)

Red Rust Proof Oats (Avena byzantina)

Hairy Vetch (Vicia villosa)

Austrian Winter Peas (Pisum arvense)

Corn (Zea mays) (variety, Yellow Washita Dent)

Pearl Kafir (Sorghum vulgare)

Dorso, red (Sorghum vulgare)

Alfalfa (Medicago sativa)

Sweet clover (Melilotus alba)

Rye, common (Secale cereale)

Barley, Michigan winter (Hordeum vulgare)

Redtop (Agrostis alba)

Timothy (Phloem pratense)

Orchard grass (Dactylis glomerata)

Bluegrass (Poa bulbvosa)

Crimson clover (Trifolium incarnatum)

Red clover (Trifolium pratense)

Brome grass (Bromus inermis)

The seed treatment consisted of:

1. Check - no treatment.

2. Long vernalization - 65 days. High temperature, 3 to 7 degrees C.
3. Short vernalization - 32 days. Low temperature, -2 to 2 degrees C.
4. Retarded germination - 65 days. -2 to 2 degrees C.
5. Advanced germination - 65 days. -2 to 2 degrees C.
6. Medium germination - 65 days. -2 to 2 degrees C.

TEMPERATURE CHART SHOWING FLUCTUATION IN TEMPERATURE READINGS FROM JANUARY 1 TO MARCH 15, 1937 (CENTIGRADE):

Upper Compartment		Lower Compartment	
Jan. 1, 1937	1 degree C.	Jan. 15, 1937	6 degrees C.
Jan. 8, 1937	2 degrees C.	Jan. 22, 1937	6 degrees C.
Jan. 15, 1937	1 degree C.	Jan. 29, 1937	6 degrees C.
Jan. 22, 1937	1 degree C.	Feb. 5, 1937	3 degrees C.
Jan. 29, 1937	1 degree C.	Feb. 12, 1937	4 degrees C.
Feb. 5, 1937	-2 degrees C.	Feb. 19, 1937	3 degrees C.
Feb. 12, 1937	-1 degree C.	Feb. 26, 1937	3 degrees C.
Feb. 19, 1937	-2 degrees C.	Mar. 5, 1937	3 degrees C.
Feb. 26, 1937	-2 degrees C.	Mar. 12, 1937	3 degrees C.
Mar. 5, 1937	-2 degrees C.		
Mar. 12, 1937	-2 degrees C.		

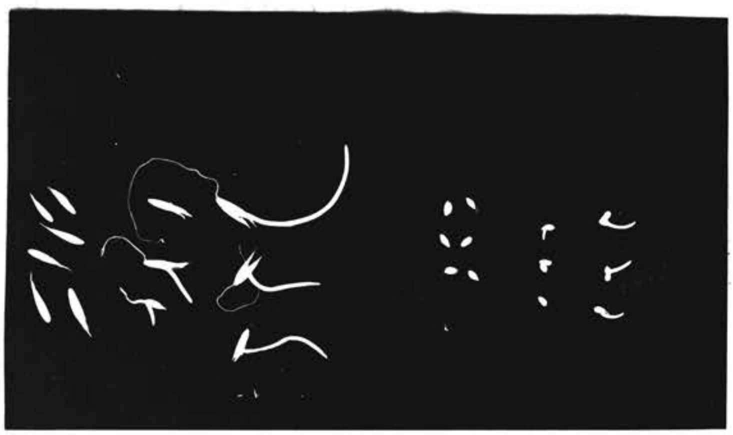
On February 5, the seed was closely examined and found to be molding. Some colonies of bacteria had also developed. Certain lots of the seed had continued to germinate, especially was this true of timothy seed which failed to germinate until it was placed in the refrigerator. Illustration 2 shows the stage of germination of the timothy seed at the time of planting. In order to retard germination and stop molding and bacterial growth, the temperature of the refrigerator was lowered. A small quantity of semesan was added to each lot of seed which was molding or had bacterial colonies.

All the seed was germinated in petri dishes at room temperature before being placed in the refrigerator. The seed which were to have a retarded germination were placed in the refrigerator just as soon as the seed showed signs of sprouting. The medium germinated seed was allowed to germinate 12 hours longer than the retarded germinated seed. The advanced germinated seed were allowed to germinate 24 hours longer than the first lot before being placed in the refrigerator.

Tap water was used to germinate the seed and no record of the amount used was kept. However, the seeds were kept moist while germinating. The same was true after the seed was placed in the refrigerator as this experiment was conducted under very ordinary conditions, and no expensive equipment was used. Each lot of seed was examined once every week and if found deficient in moisture, water was added.

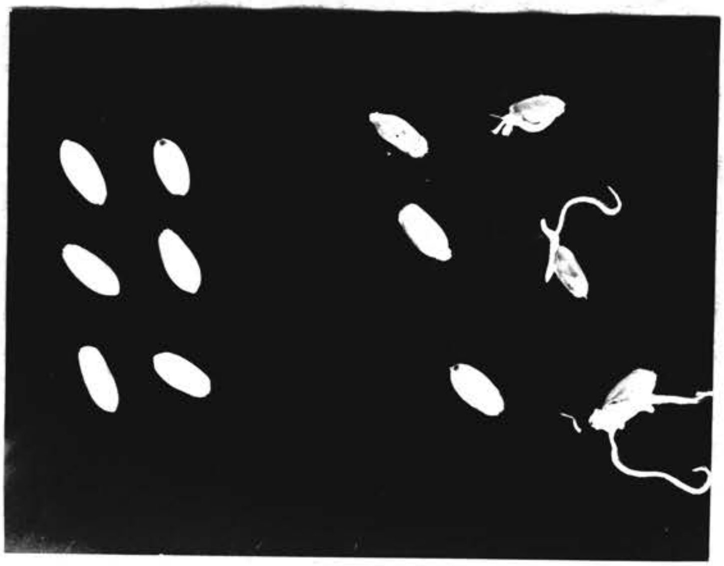
Timothy and redtop grass seed failed to germinate but were placed in the refrigerator along with the rest of the seed and given the same temperature treatment.

Plantings were made in the field (O) of the Oklahoma Agricultural and Mechanical College Agronomy Farm on March 17, 1937. These experiments were all planted in ten-foot rows, and the rows one foot apart. The soil is a sandy loam which does not crust except after heavy rains.



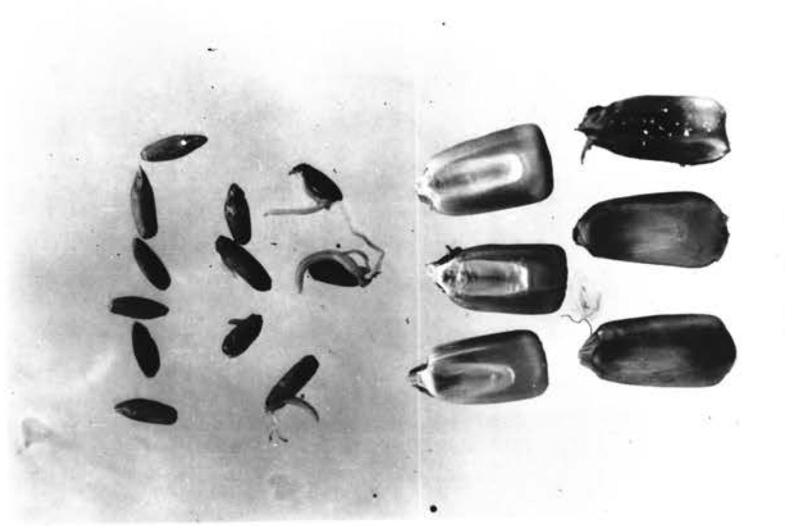
A B C D

Illustration 2. Normal and germinated orchard and timothy grass seed at the time of planting. A. Normal orchard grass seed. B. Germinated orchard grass seed showing the different stages of germination. C. Normal timothy seed. D. Germinated timothy seed. The timothy seed did not germinate until after being placed in the refrigerator.



A B

Illustration 3. Normal Fulcaster Wheat seed which was used for the check plot. B. Germinated Fulcaster Wheat seed showing the various stages of germination at the time of planting. The Fulcaster Wheat seed on the left in figure B was only slightly swollen at the time of planting, while the seed on the right shows an advanced stage of germination.



A B C D

Illustration 4. A. Normal rye seed which was used for the check plot. B. Germinated rye seed showing the various stages of germination at the time of planting. C. Normal corn seed. D. Germinated corn seed. Note the diseased condition and retarded germination of the corn seed, which no doubt accounts for the complete failure of the treated corn seed to come up after planting.

6 5 4 3 2 1

Illustration 5. Vernalized winter rye showing true response to vernalization. Row 1 or check remained in the vegetative stage and did not produce heads. Rows 2, 3, 4, 5, and 6 responded to vernalization but the severe cold treatment required to vernalize the seed lowered the germination.

5 3 2 1

Illustration 6. Vernalized Michigan Winter Barley. Note the complete failure of Row No. 1 (check) to produce heads and the injury to the germination of the vernalized rows.

DATA SECURED

TABLE 1. CHART SHOWING DATE OF FIRST APPEARANCE ABOVEGROUND, AVERAGE HEIGHT OF PLANTS ON MAY 27 AND JULY 1, BLOOMING DATE AND AVERAGE NUMBER OF CULMS PER PLANT JULY 1.

Crop	Date of First Appearance Aboveground	Average Height May 27.	Average Height July 1.	Blooming Date	Average Number of Culms
Alfalfa 1	March 30	8	19		
2					
3	April 2	8	10	July 1	
4					
5					
6					
Red Clover 1	March 30	5	21	June 20	
2					
3	April 5	5	21	June 14	
4					
5					
6					

TABLE 1. (CONTINUED)

Crop		Date of First Appearance Aboveground	Average Height May 27	Average Height July 1	Blooming Date	Average Number of Culms
Crimson Clover	1	March 30	4"	4"		
	2	April 2	4	4		
	3	April 6	4	4		
	4	April 2	4	4		
	5					
	6					
Poa bulbvosai	1	April 2	2	4		
	2	April 8	2	4		
	3	April 5	2	4		
	4	April 15	2	4		
	5	April 8	2	4		
	6	April 8	2	4		

TABLE 1. (CONTINUED)

Crop		Date of First Appearance Aboveground	Average Height May 27	Average Height July 1	Blooming Date	Average Number of Culms
Rye	1	April 2	5	5		5
	2	April 2	20	26	May 27	6
	3	April 2	20	26	May 27	7
	4	April 2	20	26	May 27	5
	5	April 2	20	26	May 27	7
	6	April 2	20	26	May 27	8
Barley	1	April 2	5	5	May 27	4
	2	April 2	10	20	May 27	10
	3	April 2	14	20	May 27	11
	4					
	5	April 2	16	20	May 27	12
	6					

TABLE 1. (CONTINUED)

Crop	Date of First Appearance Aboveground	Average Height May 27	Average Height July 1	Blooming Date	Average Number of Culms
Fulcaster Wheat 1	April 2	5	6		5
2	April 2	8	20	May 27	6
3	April 2	8	20	May 14	5
4	April 2	8	20	May 6	5
5	April 2	8	20	May 14	6
6	April 2	8	20	May 14	7
Turkey Wheat 1	April 2	5	8		4
2	April 2	5	6		4
3	April 2	8	24	June 6	10
4	April 2	8	24	June 14	7
5	April 2	8	24	June 2	8
6	April 2	8	24	June 7	9

TABLE 1. (CONTINUED)

Crop	Date of First Appearance Aboveground	Average Height May 27	Average Height July 1	Blooming Date	Average Number of Culms
Timothy 1	April 5	4	22	June 14	
2	April 5	4	22	June 14	
3	April 5	4	22	June 14	
4	April 8	4	22	June 14	
5	April 8	4	22	June 14	
6	April 8	4	22	June 14	
Brome 1	April 5	5	8		
2	April 5	5	8		
3	April 5	5	8		
4	April 5	5	8		
5	April 5	5	8		
6	April 5	5	8		

TABLE 1. (CONTINUED)

Crop	Date of First Appearance Aboveground	Average Height May 27	Average Height July 1	Blooming Date	Average Number of Culms
Orchard 1	April 5	6	7		
2	April 5	6	7		
3	April 5	6	7		
4	April 5	6	7		
5	April 5	6	7		
6	April 6	6	7		
Sweet Clover 1	April 6	10	30		
2					
3	April 6	10	30		
4					
5					
6					

TABLE 1. (CONTINUED)

Crop		Date of First Appearance Aboveground	Average Height May 27	Average Height July 1	Blooming Date	Average Number of Culms
Peas	1	April 5	14	18	May 27	
	2	April 5	14	18	May 27	
	3	April 5	14	18	May 27	
	4	April 5	10	18	May 27	
	5	April 5	16	18	May 27	
	6	April 5	16	18	May 27	
Oats	1	April 5	14	20	May 27	20
	2					
	3	April 12	12	18	May 27	18
	4	April 12	12	18	May 27	18
	5					
	6					

TABLE 1. (CONTINUED)

Crop		Date of First Appearance Aboveground	Average Height May 27	Average Height July 1	Blooming Date	Average Number of Culms
Vetch	1	April 6	8	22	June 6	
	2	April 6	8	22	June 14	
	3	April 8	8	22	June 14	
	4	April 6	8	22	June 14	
	5	April 6	8	22	June 2	
	6	April 6	8	22	June 2	
Durum Wheat	1	April 12	4	8	July 1	7
	2	April 11	4	8	July 1	7
	3	April 12	4	8	July 1	7
	4					
	5	April 12	4	8	July 1	7
	6					

TABLE 1. (CONTINUED)

Crop		Date of First Appearance Aboveground	Average Height May 27	Average Height July 1	Blooming Date	Average Number of Culms
Corn	1	April 15	30	90	June 20	
	2					
	3					
	4					
	5					
	6					
Kafir	1	April 17	18	45	July 1	
	2	April 17	18	45	July 1	
	3					
	4	April 17	18	45	July 1	
	5	April 17	18	45	July 1	
	6					

TABLE 1. (CONTINUED)

Crop		Date of First Appearance Aboveground	Average Height May 27	Average Height July 1	Blooming Date	Average Number of Culms
Darso	1	April 17	18	50	June 25	
	2	April 17	18	50	June 25	
	3	April 17	18	50	June 25	
	4	April 17	18	50	June 25	
	5	April 17	18	50	June 25	
	6	April 17	18	50	June 25	

DISCUSSION

In Table 1 it will be noted that many of the seed did not germinate. Especially is this true of the small legume seed and grasses. These particular seed could not withstand the long temperature treatment of 65 days at temperatures around 0 degrees C. However, these seed did withstand the 32-day cold period and in almost every instance gave very good results. The low germination of the seed obtained from the 65-day cold treatment may have been due to several factors. It is very evident at the time of planting that some of the seed were severely damaged by disease. This shows up plainly in the picture of the corn seed which was taken just before planting. No doubt the molds which developed on the moist seed during the vernalization process effected the percentage of germination. The consistency of low germination for those seeds which failed to germinate after vernalization for 65 days at low temperatures is very conclusive evidence that certain crop seeds cannot withstand the severe treatment which is necessary to vernalize the seed. The alfalfa and clover seed at the time of planting was very soft and spongy. This was true in every case except the check and the 32-day vernalization treatment. In almost every instance these soft seed failed to germinate, showing that long vernalization causes the seed to absorb too much moisture, which is lethal to the embryo of the seed.

Alfalfa gave some response to vernalization, but the results show that the cold treatment had a retarding effect on the plants rather than an acceleration of growth. The check gave good blooming by July 1, due to very favorable growing conditions, while the 32-day cold treatment which was the only vernalized seed with germinated gave a delayed growth and the plants failed to come into flower.

There was no response to vernalization of red clover. The check and the 32-day treatment came into blossom about the same date and were the same height at the close of the experiment July 1. The remainder of the seed failed to germinate.

Crimson clover seed seemed more hardy than some of the other clover seed as all except two of the plantings germinated; however, there was no visible response to vernalization. Growth of plants was the same for all experiments.

Poa bulbosa, which is a hardy winter blue grass producing bulblets instead of seed, gave very good germination and was able to withstand the long vernalization treatment at low temperatures. However, the percentage of germination was not as high in the treated seed as the check. There was no response or acceleration of growth due to vernalization.

Rye gave a very good response as shown by the photograph in Illustration No. 5. The check experiment did not come into flower but remained in the vegetative stage. The seed which was vernalized all came into flower fifty-six days after the seedlings made their first appearance above ground. The germination of the vernalized seed was not as good as the unvernalized check plot. There was no difference in vernalization response of the 32-day cold treatment and the 65-day treatment, which gives conclusive evidence that 32 days of cold treatment at temperatures slightly above freezing point is sufficient to completely vernalize rye.

The response of barley to vernalization was not as complete as with rye or wheat, as a few heads appeared on the vernalized check plot after the photograph in Illustration 6 was taken. This photograph also shows the effect of the cold treatment on germination of the seed. The germination of the seed was fair and all cold treatments which did not kill the seed were sufficient to vernalize the seed.

Fulcaster Wheat did not react as a true spring planted variety, but gave a winter response the same as fall-sown varieties. The check plot remained in the vegetative stage and did not produce heads. The vernalized plots gave good response to all cold treatments. No satisfactory explanation accounting for this behavior can be given at this time. The germination of the vernalized seed was not as good as the check plot. However, a satisfactory stand was obtained.

The most successful results obtained was with Turkey wheat, which was very outstanding. The check plot remained in the vegetative stage and no heads were produced. The vernalized plots came into head 62 to 67 days after the first appearance of the seedlings above ground. The 32-day cold treatment came into head 74 days after coming up, which is evidence that the short vernalization period of 32 days was not satisfactory for the best vernalization results. The germination of all Turkey wheat plots was very satisfactory.

There was no appreciable difference in the germination of vernalized and unvernalized Timothy seed. There was no response to vernalization as all plots made the same growth and flowered at the same time.

Brome grass did not respond to vernalization and did not produce flowers. The seed withstood the low temperature treatment and gave good germination.

The behavior of Orchard grass was almost identical to Brome grass as it did not respond to vernalization or produce flowers.

Sweet clover seed could not endure the long vernalization treatment and the seed was killed. The check plot and the 32-day cold treatment made good growth but did not respond to vernalization.

Austrian winter peas did not respond to vernalization but gave good germination. The seed was able to endure the severe cold treatment and made a normal growth, but there was no acceleration of flowering.

Winter oats behaved as a spring-sown crop and produced normal grain with no acceleration of growth due to vernalization. The germinated vernalized seed was all injured by the cold treatment. The check plot germinated very satisfactorily, while the stand of the vernalized plots was very poor and irregular, even the 32-day cold treatment injured the seed.

Hairy vetch endured the cold treatment, and every plot gave satisfactory germination. There was no response to vernalization as all plots made about the same growth and flowered at the same time.

Durum wheat germinated very poorly and only a few scattered heads appeared even on the check plot. However, the germination was higher on check plots than the vernalized plots.

Corn was the most sensitive of any of the seed to the vernalization treatment. A good stand on the check plot was obtained. No plants appeared in the vernalized plots. The treated corn seed was very discolored and damaged by disease at the time of planting.

Kafir did not respond to the vernalization treatment. The cold treatment injured the seed and gave poor germination of all treated plots.

Red darso is not as sensitive to vernalization treatment as some other crops, as good stands in all plots were obtained. There was no response to vernalization in any noticeable degree.

At the close of the experiment the number of culms per plant was counted and averaged for Winter Rye, Michigan Winter Barley, Fulcaster Wheat, Turkey Wheat, Red Rust Proof Oats and Durum Wheat. The result of this count is shown in Column 6 of Table 1. It will be noted that in every case where there was a definite response to vernalization the average number of culms per plant was higher than for the check plot for that particular crop. The vernalized plot which did not respond to vernalization gave an average count very similar to the check plot for the same crop.

The seed from the plots producing mature heads was not harvested so as to determine the yield per acre. Harvesting was not carried out at the close of the experiment as planned at planting time due to the fact that poor, irregular stands made it impracticable, and satisfactory results could not be obtained.

SUMMARY

Turkey Wheat, Michigan winter barley and Winter rye seed, germinated and held at temperatures slightly above freezing for periods of 65 days and planted in the spring of the year came into head about the same time as untreated seed planted in the fall of the year. Untreated seed of the same varieties failed to head and remained in the vegetative stage.

Durum wheat will not germinate at the same moisture content as other varieties of wheat. Excessive moisture causes the seed to become very soft which apparently injures the germination of the seed.

It is not necessary in vernalizing seed to have them in a sprouted condition (visible sprouts) at the time they are placed in the refrigerator. Slightly swollen seed which showed no visible sprouts at the time of planting gave as good a response to vernalization as the seed in an advanced stage of germination.

Drying the seed after vernalization and prior to planting did not nullify the vernalization treatment as the seed remained in dry, loose soil several days before sufficient moisture was received to bring the seedlings above ground.

Spring-sown crops did not respond to the vernalization treatments. The treated seed in most cases made the same growth and flowered at the same time as the untreated seed.

In no instance was the germination of the treated seed

equal to the untreated seed. Vernalization definitely injures the germination of seed. This was true even for the 32-day cold treatment.

The practical application of vernalization of field crops under Oklahoma conditions is very doubtful until further experimental work has been carried on. In cases where fall-sown crops cannot be planted due to insufficient rainfall it is altogether possible to vernalize the seed and produce a normal yield. In most instances the failure of fall-sown crops is not determined until it is too late to vernalize the seed.

In plant breeding work where the rapid increase of progenies is desired the vernalization principle can be made use of to an advantage.

The forcing of vegetable and truck crops in the South has received much attention in the past. Any method which will accelerate or shorten the vegetative period of these crops would be valuable to operators of greenhouses and truck farms. There is no reason why vernalization cannot be applied to vegetable crops.

The value of vernalization to the average farm will be limited until some satisfactory method of seed pre-treatment is worked out. The average farm is not equipped to vernalize seed, and too much difficulty is encountered with the seed molding and in controlling the moisture content of the seed during treatment.

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