Temperature Alternation and Germination of Vegetable Seed [1].

By

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In a previous paper the writer reported on the germination of vegetable seed at constant temperatures (Kotowski, 3). Extending the work, the influence of alternation of a range of temperatures was studied and the results of this investigation are presented herewith.

Harrington (2) and Morinaga (4) have summarized the literature on this subject and have contributed to our knowledge of seedlings grown in alternating temperatures, but their results were obtained in germination dishes. In the writer's experiment all the work was carried on in soil.

The seeds were sown in flats (60 × 48 × 10 cm). The medium for germinating was pure quartz sand, rather coarse. The layer of sand was 5 cm deep. The seeds were placed in rows 2 cm deep and 5 cm apart, except peas which were put 3 cm deep. The sand was saturated (35 per cent air dried weight) with water continuously, the temperature of water added being 13—15° C.

The apparatus used consisted of a set of constant temperature chambers with electrical control. Equal temperature throughout the chamber was secured by means of an electric fan. The flats were transferred from one chamber to another according to the alternation of temperatures chosen for each series.

For each species three replications of 100 seeds each were employed, except pea and cucumber, one test of which was restricted to 50 seeds.

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[1]) Work done at Davis, California, Division of Truck Crops, University of California while on leave from College of Agriculture, Warsaw, Poland.

Examination of the cultures began 24 hours after planting. Seedlings were picked out as they appeared, on 24 hour intervals.

The experiments ran in six series. Series A, B und C were under observation for 30 days; D, E and F for 15 days. The temperatures for the 24 hour period are indicated in Table I, where also the results may be found.

The coefficient of velocity of germination reported in Table I and III was derived from this formula:

$$\text{Coefficient of velocity} = \frac{A_1 + A_2 + \ldots\ldots + A_x}{A_1T_1 + A_2T_2 + \ldots + A_x T_x}$$

Where: A — the number of seedlings picked out, T — the number od days after planting, corresponding to A. This formula expresses in one term the relations between the rate of growth through the sand layer and the number of seedlings obtained. The more rapid the germination, the larger the coefficient.

Series A, B and C.

Series A produced the highest number of seedlings in beet, carrot and lettuce (cfr. table I). The germination of tomato was the best in series C and for onion, radish and pea any of the alternation of temperatures chosen within Series A, B and C seemed to have the same effect in seedlings production. Beet exhibited an evident check in germination in Series B and C, and lettuce was also somewhat retarded. Cucumber germinated poorly in Series A and B, giving no seedlings in Series C. This species, when transferred after 30 days to constant temperature 25^0 C, germinated quickly and gave 90 per cent. The failure of germination in Series C is hard to explain and some additional investigation is planned for this purpose. The percentage of seedlings obtained at constant temperatures (cfr. Kotowski, 3) corresponding to the low and high temperatures used in alternation is shown in Table II, and from these numbers the arithmetical means are given. They may represent the assumed values to be expected when alternating these constant temperatures. In this way we thought to find the effect of alternating on seedlings production. The calculated values, shown in Table II, are confronted with the percentage of seedlings in Table I. This comparison records some advantageous effect of alternating only for onion and unfavorable effect on beet and pea. For the other species no effect of alternating, positive or negative, is evident.

It seems reasonable to conclude that in our experiments the use of alternating temperatures in Series A, B and C did not increase the per cent of germination.

The rapidity of seedlings to protrude through the sand layer may be compared for Series A, B and C from the coefficients of velocity of germination recorded in Table I. The coefficients increased when the low temperatures (4—8—11^0 C) were gradually raised. The increase of coefficients is most marked in species whose seeds did not germinate at constant temperatures as low as 4, 8, or 11^0 C. For instance, tomato seeds began germination in constant temperature at 11^0 C (Kotowski, 3) and now this species yielded the highest increase of coefficients of velocity of germination, expressed in relative numbers from 100 to 163. Onion and carrot, which initiated germination in constant temperature at 8^0 C, represent also a distinct increase of coefficient. Pea was a species that germinated well at 4^0 C, constant temperature, and in alternating temperatures for this plant the increase of coefficient of velocity was very moderate (from 100 to 117). But we can notice also that lettuce germinated quite well at 4^0 C constant, and nevertheless in the present series the increase of coefficient of velocity of germination was for this plant high (from 100 to 143).

The ratios stated here owe their origin in the processes of growth, possibly mostly related to biochemical work going on in the seedlings and therefore in the present contribution it would be premature to give any suggestion for explaining the facts referred to.

The coefficient of velocity lead also to the conclusion that the growing processes were accelerated when alternating temperatures acted. To support this opinion, Table III can be consulted, in which two kinds of coefficients are recorded. The calculated values of coefficients derived from the formula:

$$\frac{2}{3}x + \frac{1}{3}y = z$$

Where: x — the coefficient of velocity of germination at constant low temperatures, i. e. 4, 8 and 11^0 C respectively, y — the same for high temperature (25^0 C), z calculated coefficient for alternating temperatures, x and y used as stated in my previous paper (Kotowski, 3).

If we compare these two kinds of coefficients, we can measure quantitatively the effect of alternating temperatures. This effect is expressed as difference between the coefficient of velocity found and the coefficient calculated. When the difference is positive it means that the speed of growth was favorably affected by alternating temperatures. In our case, for Series A, B and C, this fact took place for all plants except for pea, where distinct negative differences were observed, indicating rather an inhibition of growth by alternating temperatures. The behavior of pea, a legume plant, is like that of bean, for which species long ago Godlewski (1), reported that sudden changes of temperatures decreased the rate of growth of epicotyls.

Series D, E and F.

The series in question represented a reserved combination of temperatures as the former ones. The production of seedlings was the best in Series F, for all species used, except for lettuce (cfr. Table I). In Series D, some of the species exhibited lower seedlings production than in Series F (onion, beet, pea, carrot and cucumber) but for the others, the raising of temperatures (4—8—11^0 C) did not produce such effect (radish, tomato, lettuce). Probably the limiting factor for germination in Series D, E and F was the exposure of flats to low temperatures during 8 hours daily, and this factor promoted more influence on seedlings production than the exposure for 8 hours daily to high temperature (25^0 C) in Series A, B and C.

The comparison between Series A, B and C versus Series D, E and F, approves the fact, that more advantageous for the seedlings production was alternation of long duration of low temperatures (16 hours daily) with short one of high temperature (8 hours daily), than the reverse one. This view is in accordance with that of Harrington (2) who says, that an alternation between 20^0 C for 16—18 hours and 30^0 C for 6 to 8 hours each day gives good results in germination of parsnip, celery, redtop *(Agrostis palustris)* and orchard grass *(Dactylis glomerata)* seed.

But the greater production of seedlings in Series A, B and C was not common for all species tested. Equal number of seedlings throughout all series occurred in radish, onion and tomato. Beet and cucumber seemed to find better germination conditions within Series D, E and F than within Series A, B and C.

As far as the coefficients of velocity of germination are concerned, the changes of low temperatures in Series D, E and F contributed but little to their raising, indicating that the rate of growth of seedlings was influenced by long exposures to high temperature that did not change for the Series D, E and F. Accordingly, the ratios of coefficients between Series D and F vary from 100 to 115 for 5 species, for 2 species are from 100 to 122, and only for lettuce reach the ratio 100 versus 134.

The speed of germination was in Series A and C different to that in Series D and F, for most of the seeds used. When determined the coefficients in Series A and D as 100, we can record the following numbers for Series C and F:

Tomato: 163 and 111
Carrot : 153 and 117
Onion : 149 and 115
Radish : 147 and 114

Only pea presented a different ratio: 117 and 122, which seemed to support the opinion that for this species any of the alternating temperatures acted favorably on the rate of growth.

The ratios cited above are a further proof that the rate of growth is increased fairly quick when the plants are exposed to low temperature acting 16 hours, if little increase of these temperatures results. We have stated elsewhere (Kotowski, 3) the rapid increase of coefficients of velocity obtained by tests done in constant temperature at 4^0 C versus 8^0 C, or 8^0 C versus 11^0 C and we have observed little differences in coefficients if compared within the range of 25 and 30^0 C.

Assuming, that the exposure during 16 hours exercised more profound influence on the rate of growth than the exposures during 8 hours, we find the coefficients in Series A, B and C against that in Series D, E and F, varying in the trends as what may be expected in agreement with previous observations.

The stimulation of growth, when measured in Series D, E and F in the same way as in Series A, B and C, can be demonstrated (cfr. Table III) for all species, except pea and lettuce, where rather the growth was checked. The formula for calculated coefficients in Series D, E and F was changed, according to other temperature combinations, as follows:

$$\frac{1}{3}x + \frac{2}{3}y = z,$$

x, y and z remaining like in equation used for Series A, B and C.

Summary.

Eight species were studied and six kinds of alternations of temperature were used.

1. The alternation of temperatures in this experiment did not increase the percentage of seedlings.

2. The daily use of low temperatures (4, 8 and 11^0 C) during 16 hours in connection with high temperature (25^0 C) during 8 hours, gave better results than the reserve combination.

3. The coefficients of velocity of germination vary according to the change of lower temperatures. The rate of increase of the coefficients was dependent to the effect involved by temperature acting daily 16 hours.

4. The stimulation of growth of seedlings, as consequence of alternation of temperatures, was stated for most of the species studied.

Acknowledgements.

The writer wishes to acknowledge the support afforded through a research fellowship granted by the International Education Board that enabled him the performance of this investigation.

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Table I. Germination of Seeds.

	Onion	Beet	Radish	Pea	Carrot	Tomato	Cucumber	Lettuce
Series A. 16 h 4^0 C + 8 h 25^0 C.								
First seedling, days after sowing	14	9	7	8	16	17	19	7
Last seedling, days after sowing	24	24	14	14	23	24	27	14
Seedlings in per cent of seed sown	96	96	80	54	56	70	29	97
Coefficient of velocity of germination	5·9	8·1	12·2	9·8	5·6	5·1	4·6	10·7
Series B. 16 h 8^0 C + 8 h 25^0 C.								
First seedling, days after sowing	11	8	5	7	11	12	14	6
Last seedling, days after sowing	20	16	9	20	19	22	21	13
Seedlings in per cent of seed sown	91	48	82	57	50	88	16	84
Coefficient of velocity of germination	7·3	9·5	14·5	10·7	6·9	6·2	5·4	12·2
Series C. 16 h 11^0 C + 8 h 25^0 C.								
First seedling, days after sowing	9	7	5	5	9	9	—	5
Last seedling, days after sowing	16	11	8	15	14	15	—	10
Seedlings in per cent of seed sown	90	14	82	54	48	91	—	74
Coefficient of velocity of germination	8·8	11·5	17·9	11·5	8·6	8·5	—	15·3
Series D. 8 h 4^0 C + 16 h 25^0 C.								
First seedling, days after sowing	8	5	4	5	8	6	6	4
Last seedling, days after sowing	12	12	6	6	12	11	12	12
Seedlings in per cent of seed sown	79	62	85	36	39	89	38	65
Coefficient of velocity of germination	10·2	14·0	21·6	18·2	10·3	12·5	14·7	13·8
Series E. 8 h 8^0 C + 16 h 25^0 C.								
First seedling, days after sowing	7	5	4	5	8	6	5	4
Last seedling, days after sowing	12	9	6	8	12	11	7	11
Seedlings in per cent of seed sown	89	71	81	24	48	88	40	48
Coefficient of velocity of germination	11·2	17·0	22·8	16·5	10·9	12·9	16·1	14·5
Series F. 8 h 11^0 C + 16 h 25^0 C.								
First seedling, days after sowing	7	4	3	4	7	6	5	4
Last seedling, days after sowing	11	8	5	6	10	10	8	9
Seedlings in per cent of seed sown	95	93	84	57	48	93	62	60
Coefficient of velocity of germination	11·7	17·0	24·6	22·2	12·0	13·8	16·7	18·4

Table II. Germination of Seeds (cfr. Kotowski, 3).

Percentage of seedlings.

Const. Temp.	4° C	25	Av.	8	25	Av.	11	25	Av.
Onion	—	91	—	82	91	87	86	91	89
Beet	—	122	—	110	122	116	131	121	126
Radish	42	97	70	80	97	89	92	97	95
Pea	84	82	83	87	82	85	88	82	85
Carrot	—	52	—	58	52	55	56	52	54
Tomato	—	96	—	—	96	—	75	96	85
Cucumber	—	89	—	—	89	—	—	89	—
Lettuce	86	98	92	87	98	93	91	98	95

Table III. Coefficients of velocity of germination.

		Onion	Beet	Radish	Pea	Carrot	Tomato	Cucumber	Lettuce
Series A.	(4 + 25)° C								
	Calculated	—	—	11·1	10·2	—	—	—	9·8
	Found	5·9	8·7	12·2	9·8	5·6	5·1	4·6	10·7
Difference		—	—	+ 1·1	− 0·4	—	—	—	+ 0·9
Series B.	(8 + 25)° C								
	Calculated	6·0	8·4	14·0	12·8	6·4	—	—	12·0
	Found	7·3	9·5	14·5	10·7	6·9	6·2	5·4	12·2
Difference		+ 1·3	+ 1·1	+ 0·5	− 2·1	+ 0·5	—	—	+ 0·2
Series C.	(11 + 25)° C								
	Calculated	7·3	10·0	16·2	14·5	7·6	8·1	—	13·7
	Found	8·8	11·5	17·9	11·5	8·6	8·5	—	15·3
Difference		+ 1·5	+ 1·5	+ 1·7	− 3·0	+ 1·0	+ 0·4	—	+ 1·6
Series D.	(25 + 4)° C								
	Calculated	—	—	19·9	18·3	—	—	—	16·8
	Found	10·2	14·0	21·6	18·2	10·3	12·5	14·7	13·8
Difference		—	—	+ 1·7	− 0·1	—	—	—	− 3·0
Series E.	(25 + 8)° C								
	Calculated	9·2	12·9	21·3	19·6	9·4	—	—	17·9
	Found	11·2	17·0	22·8	16·5	10·9	12·9	16·1	14·5
Difference		+ 2·0	+ 4·1	+ 1·5	− 3·1	+ 1·5	—	—	− 3·4
Series F.	(25 + 11)° C								
	Calculated	9·9	13·8	22·4	20·5	10·0	12·3	—	18·8
	Found	11·7	17·0	24·6	22·2	12·0	13·8	16·7	18·4
Difference		+ 1·8	+ 3·2	+ 2·2	+ 1·7	+ 2·0	+ 1·5	—	− 0·4

(Wpłynęło do redakcji 18 maja 1927 r.).