High Temperature Studies of Sugar Beet Germination

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Sugar beet growers in California's Imperial Valley have an annual problem of securing adequate stands of sugar beets in the early part of the planting season (August to mid-September). As the season progresses the problem becomes less severe and suggests that excessively high soil temperature is the causal factor. Soil temperatures under germinating conditions of at least 41°C have been recorded.

The optimum sugar beet germination temperature has been reported to occur at an alternating temperature of 20°C for 16 hours and 30°C for 8 hours (2,3,15)[2]. In addition, standard testing procedures recommend soaking the seed in water at least two hours before testing in order to leach a reported endogenous inhibitor. Stout and Tolman (12) stated that sugar beets contain a toxic substance and that the amount of this substance varies from variety to variety, and within a variety from year to year depending on soil and climatic conditions and maturity of the seed at harvest. They later reported that this substance was ammonia (13). However, DeKock and his co-workers (3) did not feel that excess ammonia was the cause of poor germination. DeKock and Hunter (2) isolated a "yellow saturated oil from the water extract of beet seeds which acted as a powerful inhibitor of germination when tested on cress (*Lepidium sativum*) and other seeds." Makimo and Miyamoto (7) stated that the principle inhibitor in sugar beets was oxalic acid.

Pertinent information on the high temperature-germination problem is lacking. The problem has been attacked only incidentally in conjunction with germination inhibitors and promotors. Numerous workers have attempted to overcome dormancy and/or inhibitor effects by leaching or application of promoters. Mikkelsen and Sinah (9) reported that soaking rice seed in a solution of 1 part commercial bleaching solution (5.25% NaOCl) to 100 parts water removed the inhibitor without affecting germination. In addition, NaOCl increased rate and uniformity of germination as well as stimulating seedling development.

The inhibitor in sugar beets may not be specific. Evenari

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[2] Numbers in parentheses refer to literature cited.

(4) pointed out that the inhibitor found in sugar beets inhibited germination in seeds of 28 species belonging to 14 families.

Many attempts have been made to improve germination with gibberellin. Reports indicate that gibberellin may offset the effects of high temperature, osmotic pressure, coumarin and gamma radiation, or it may cause light-sensitive seed to germinate in the dark (6). The effect of gibberellic acid seems to be similar to that of light in promoting germination, but it is far more effective than red light in reversing the high temperature inhibition of germination in lettuce (8).

Snyder (11) found that soaking seeds or seedballs of sugar beets in 10,000 ppm gibberellic acid did not hasten germination. He also reported that dust treatments with gibberellic acid on sugar beets at the recommended rates and twice recommended rates gave no significant responses to germination. Spray treatments of gibberellic acid on seeds produced no differences in stand count or vigor (10).

Nitrates have long been known as powerful agents in germination, particularly in after ripening and in light sensitive seed (6).

Thompson (14) showed a very significant increase in germination of endive seed when the seed had been soaked 4, 8, 16 and 24 hours in a 0.5% solution of thiourea, dried, stored at 18° - 25°C for 10 days and then germinated at 30° - 31°C. Crocker and Barton (1) treated lettuce seed with a 0.5% thiourea solution and obtained the highest germination at high temperatures.

A number of experiments were set up to explore some of the factors that might influence germination at high temperatures. The assumption was made that if it were possible to increase germination at elevated temperatures, the logical approach would be to leach out some inhibitor or add some promoter which might allow germination to proceed.

Preliminary to these tests, optimum conditions for temperature, moisture, and leaching were established and these conditions were followed throughout the experimental procedure.

Methods and Procedures

Four sugar beet varieties, all of which are grown commercially in the Imperial Valley, were used in the experiments. HH3, US75, and HC-1 are multigerm varieties. HH4 is a monogerm variety.

Preliminary tests showed that the most consistent results were obtained by germinating the seeds on blotters which were placed on Kimpak germinating paper, enclosed in plastic germinating dishes, and placed in a Mangelsdorf germinator. Approximately 60 ml of distilled water or germinating solution provided the free moisture necessary for germination (5). Treatment consisted of 50 seeds per dish with 4 replications.

For the purpose of establishing germination percentage only normal healthy radicles more than 1 mm in length were counted. In accordance with standard seedling interpretation (15) more than 1 seedling developed from a seed ball was considered as only 1 count. Size of the seed was 7½ to 9½/64 inch.

Inhibitors Oxalic acid was added to the germinating medium in concentrations from 0.001% to 1.0% and germination was carried out at 20° and 45°C. In a second experiment, seeds were soaked in 0.05% NaOCl for 24 hours in an attempt to remove some inhibitor which might be more active at high temperatures than at low ones.

Promoters From a number of chemicals shown to promote germination in other species, gibberellin, KNO_3, and thiourea were chosen for experimentation in improving high-temperature germination. Gibberellin (82% potassium gibberellate) was added to the germinating medium at rates of 10^{-5}, 10^{-4} and 10^{-3}M. Potassium nitrate was applied at concentrations of 10^{-4}, 10^{-3}, 2×10^{-3}, and 4×10^{-3}M. Seed were soaked in a 3% solution of thiourea for 5, 10 and 20 minute periods, then transferred to the distilled water germinating medium. All chemical promoter experiments were conducted at 20° and 45°C.

Results

In these tests HH3 was a rapid germinating variety, HH4 was slowest, and HC-1 and US75 were intermediate (Table 1). Preliminary tests showed that 20°C constant temperature gave a higher germination percentage than the recommended 20° - 30° C alternating temperature, which in turn was superior to a 30°C constant temperature (Table 2).

There was no significant difference in germination percentage between seed washed for 2 hours in running tap water, and

Table 1.—Percent germination of 4 commercial varieties of sugar beets at 20°C.

Variety	3 Days	7 Days	10 Days	14 Days
HH3	86.5	95.0	95.5	95.5
US 75	58.0	81.5	84.5	84.5
HC-1	57.0	77.0	79.5	79.5
HH4	10.5	40.5	50.0	50.0

$LSD_{.01}$ = 4.1

Table 2.—Percent germination of sugar beets in 3 temperature regimes.

Variety	20° Constant	20° - 30° Alternating	30° Constant
HH3	95.5	90.0	83.0
US 75	84.5	70.5	51.0
HC-1	80.5	76.0	52.0
HH4	55.0	31.5	12.5

$LSD_{.01}$ = 5.9

unwashed seed. Therefore, unwashed seed was used throughout the experiment.

Inhibitors Seed soaked in oxalic acid at concentrations ranging from 0.001% to 1.0% were inhibited as concentration increased. (Table 3). At optimum germinating temperature, oxalic acid was without effect until concentrations near 1.0% were reached.

Table 3.—Germination percentage of sugar beet varieties HH3, HH4, US 75 and HC-1 in various concentrations of oxalic acid at 20° and 45°C constant temperatures.

	20°C				45°C			
Concentration	HHS	US75	HC-1	HH4	HH3	US75	HC-1	HH4
1.0%	50.5	42.0	43.5	16.5	0	6.0	2.0	0
0.1%	96.0	85.0	86.5	48.5	1.5	27.5	3.5	.5
.01%	95.5	82.0	80.5	50.5	1.0	16.0	2.0	0
.001%	94.0	82.5	80.0	42.5	10.5	15.0	4.0	0
Untreated	95.5	79.0	82.5	53.0	20.5	19.0	.5	2.0

$LSD_{.01}$ = 5.5

Soaking seed with NaOC1 solution for 24 hours had little influence on germination, although germination of varieties HC-1 and HH4 were slightly inhibited at 20°C (Table 4). All varieties were slightly inhibited by NaOCl at 45°C.

Table 4.—Germination percentage of 4 varieties of sugar beet seed soaked 24 hours in NaOCl solution.

	20°C		45°C	
Variety	Treated	Untreated	Treated	Untreated
	%		%	
HH3	91.5	96	10.0	40.0
US 75	73.5	78	1.0	14.0
HC-1	67.5	79.5	2.0	10.5
HH4	44.0	60	0	2.0

$LSD_{.01}$ = 8.4

Promoters Gibberellin had no effect on germination when applied to the germinating medium at concentrations ranging from 10^{-3} to 10^{-5}M (Table 5). Likewise, KNO_3 and thiourea failed to produce a stimulatory effect on germination. Germination was not influenced at either 20° or 45°C.

Table 5.—Germination percentages of sugar beet seeds in concentrations of 10^{-3}, 10^{-4}, and 10^{-5}M solutions of gibberellic acid.

	20°C				45°C			
Gibberellin	HH3	US75	HC-1	HH4	HH3	US75	HC-1	HH4
10^{-5}M	95.0	79.5	81.5	45.0	0	0	0	0.5
10^{-4}M	96.0	79.5	80.0	40.5	0.5	0	0	0
10^{-3}M	96.0	81.5	81.0	49.5	0.5	4.0	0.5	0.5
Control	95.0	81.5	77.0	40.5	0.5	1.0	0	0

$LSD_{.01}$ = 4.6

Discussion

All indications point to unusually high temperature as the primary problem in sugar beet germination under field and laboratory conditions. At the beginning of these experiments, soil temperature data were not available for the Imperial Valley. Since that time, information has become available which indicates that field temperatures at germination depth may exceed 41°C in a moist soil and 68°C in a dry soil.[3]

Laboratory experiments arbitrarily used 45°C as a maximum germinating temperature. No experimental treatment used (leaching of inhibitors, addition of promoters, etc.) was able to improve seed germination significantly at this temperature. However, the threshold point at which germination significantly improves is at 42-43°C. Thus one might expect to improve germination by certain experimental manipulations at the 42-43°C level.

It is noteable that certain standard procedures, e.g., leaching inhibitors and germinating at 20° — 30°C alternating temperature, failed to improve germination and in some cases actually inhibited germination.

These data give no evidence to support the theory that sugar beet seed contains an active inhibitor at concentrations sufficient to prevent germination. If oxalic acid were the germination inhibitor present, one might expect physiological concentrations to inhibit germination. In the case of the 4 varieties tested, germination was not decreased (at optimum germination temperature) until concentrations reached 1.0% (Table 4). Likewise, certain substances reported to promote seed germination failed to produce a response in these tests.

No doubt, varietal responses vary greatly under extreme germinating conditions. Of the varieties tested, HH3 and US75 responded markedly when the temperature was dropped from 45° to 43°C, whereas HC-1 and HH4 were only slightly stimulated. Thus, varietal selection for potential to germinate at elevated temperature may be an important tool for growers who must plant in summer.

Under field conditions there can be no doubt that salt may also play a large role in rate and degree of germination. The salt tolerance-moisture-temperature relationship will be investigated in future experiments.

Summary

Various germination inhibitors and promoters have been investigated in an attempt to improve field germination of sugar

[3] The authors gratefully acknowledge the assistance of Mr. George Worker in furnishing temperature data for the Imperial Valley.

beets under unusually high soil temperature. No treatment studied has been able to improve germination percentage at 45°C constant temperature. However, when the temperature is decreased to 43°C, considerable germination occurs. Varietal selection for heat-tolerant seed may lead to improved stands in problem areas.

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