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GIBBERELLIC ACID BREAKS DORMANCY and hastens germination of CREEPING SAGE

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Abstract: Creeping sage *(Salvia sonomensis* Greene*)*, a semi-shrub, is useful for plantings to reduce fire hazard and to stabilize soil. The most effective, practical, and lasting technique to break seed dormancy was a soaking in gibberellic acid under constant agitation at 500 p.p.m. for 4 hours. Lesser concentrations of this acid and shorter soaking periods were satisfactory if the seeds were planted soon after treatment and if soil moisture and other conditions favored germination. Sulfuric acid, thiourea, hydrogen peroxide, hot water, and gibberellic acid slurry—used alone or in various combinations—were not as effective as the gibberellic acid soak and, in some instances, seriously damaged the seed.

Oxford: 176.1 *Salvia sonomensis:* 232.315.3:161.4GS.

Retrieval Terms: Salvia sonomensis; seed dormancy; seed treatments; gibberellic acid.

Creeping or Sonoma sage *(Salvia sonomensis* Greene*)* is a squat, spreading, semi-deciduous aromatic subshrub that has shown promise for planting to reduce fire hazards in areas cleared of high volume, flammable chaparral. Native to the foothills of the Sierra Nevada and Coast Range in California, this plant forms extensive colonies which develop mostly from stem layers formed along the branches. The foliage practically blankets the ground and smothers herbaceous species known to produce flashy fuels through which fires spread rapidly *(fig. 1)*.

This species is now being planted to provide soil protection—especially where a low volume cover is needed, such as along highway cut and fill slopes and on fuel-breaks (wide strips of land cleared of heavy brush to break extensive brushfields into fire-manageable units). Most foliage of creeping sage is within 6 inches of the ground, and occasional, non-persistent flower spikes are usually less than 12-inches tall. This species grows rapidly and is adapted to many sites in the chaparral zone in California. Test plantings using rooted transplants as well as non-rooted cuttings have been successful, but practically all direct seedings have failed. Most of these failures are attributed to poor seed germination.

Like many other wildland plants, creeping sage does not germinate well even when moisture, temperature, and other conditions are favorable. Stratifying the seed for 90 days breaks the dormancy,[1] but this method of inducing germination has proved impractical except in greenhouse and nursery plantings. Planting seed to overwinter in the ground is uncertain because soil moisture and temperature conditions are generally not suitable for sufficient periods to effectively break dormancy throughout the areas where creeping sage grows naturally or in other places where it may be adapted and used in planting programs. The chief deterrence to dormancy lies in the seed coat—

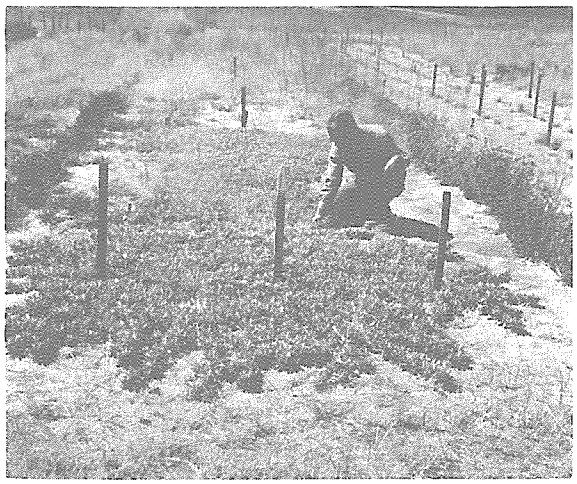

Figure 1—*Creeping sage transplanted along a single row (center) have spread within 2 years 6 to 8 feet across and nearly blanket the ground, at 5,000 feet elevation on the San Bernardino National Forest, Riverside County, California.*

not in the embryo, as indicated by high germination (generally more than 70 percent) when seed coats are removed compared to 10 percent or less germination of intact seeds.

Using existing methods and materials which are effective against seed dormancy in other species, we tried sulfuric acid, thiourea, hydrogen peroxide, hot water, and gibberellic acid (GA) alone or in various treatment combinations to find how to improve germination of creeping sage seed. We also tried stratification. In these trials, gibberellic acid was the only treatment other than stratification which showed any promise for improving germination. Accordingly, we sought to develop feasible methods for applying gibberellic acid and to determine effects various applications of this material had on germination directly after treatment and several months thereafter. Germination was substantially and significantly improved by gibberellic acid at all concentrations and soaking periods used. Soaking creeping sage seed in gibberellic acid yielded up to a twentyfold increase in total germination and required only about one-half the time it took untreated seed to germinate.

METHODS

The effects of gibberellic acid on the amount and speed of creeping sage germination were tested by using a potassium gibberellate salt on seed collected in May 1968 in Lake County, California. Seed used were held on a 1/25-inch diameter sieve and averaged 50 percent or higher fill as compared to only about 12 percent fill of discarded seed that passed through the sieve.

The main treatments were (a) soaking in gibberellic acid; (b) application of gibberellic acid slurry; (c) stratification for 3 months; and (d) excising embryos. An untreated lot served as controls.

The treated seed was either soaked in gibberellic acid solutions of 100, 200, or 500 p.p.m. for 1/4-, 1/2-, 1-, or 4-hour periods or mixed with slurry to adsorb the material, and then air-dried before being placed to germinate. The slurry was prepared by blending "Gibrel"[2] a 5 percent potassium salt of gibberellic acid, with distilled water to the consistency of thick cream.

Seed to be stratified was enclosed in fine mesh plastic screen envelopes embedded in moist vermiculite held in tightly sealed polyethylene bags and refrigerated at 35°F. for 90 days before they were tested. Separate portions of seed soaked for 1/2 to 4 hours at each solution concentration used were air-dried, sealed in plastic bottles and refrigerated at 35°F. Samples of seed soaked 1 hour were tested after 4 months' storage, and all the seed treatments represented, except the 1/4-hour soak, were tested for germination after 11 months' storage. In two other treatments, a portion of the stratified seed was soaked 4 hours in 500 p.p.m. gibberellic acid, and one lot of seed was treated with gibberellic acid slurry.

Germination trials were started 2 to 4 days after the seeds were treated with gibberellic acid or removed from storage. Except in a test in which 100 excised seeds were used, all tests had four replications of 100 for a total of 400 seeds uniformly spaced on premoistened, indented blotters in covered petri dishes. Germination tests were conducted in August and September 1969, except stratified seeds were tested 3 months later, and stored seeds were tested 4 and 11 months later.

The petri dishes were arranged in a randomized block design in room temperature ranging from 70 to 82°F. Preliminary tests had suggested that creeping sage germinated somewhat better in the dark than in the light, so petri dishes were covered with black plastic sheets. Seeds with 1/16-inch radicles were considered germinated; these were tallied and removed daily during the first 15 days and every 2 to 3 days thereafter until seeds germinated or 30 days had elapsed, except for gibberellic acid slurry-treated and the untreated seeds, which were maintained for 50 days.

Cumulative germination data based on percentages of filled seed were transformed by arc sin before

making analysis of variance and applying Duncan's Multiple Range Test.

RESULTS

Treating creeping sage seed with gibberellic acid produced up to a twentyfold increase in total germination and considerably hastened germination. The treatment was equally as efficient in breaking dormancy and in speeding up germination as stratification. And in certain instances, it was nearly as effective as excised embryo technique used to provide an estimate of germination potential. All gibberellic acid treatments produced significantly higher germination than untreated seeds and most were not significantly different from stratified seed.

Applied either by soaking or slurry, gibberellic acid treatments yielded from 33 to 62 percent total germination as compared to 3 percent for untreated, 54 percent for stratified, and 70 percent for excised embryos *(table 1)*. The highest initial germination (62 percent) for intact seed resulted from gibberellic acid soak for 1 hour at 100 p.p.m. This rate of germination was significantly higher than that resulting from some of the other treatments. Results from these tests made directly after treatments were not clear-cut, however, in regards to total germination according to method (soak or slurry), concentration, or soaking period with gibberellic acid.

A test with seeds stored for 4 months and then soaked for 1 hour at a gibberellic acid concentration of 100 p.p.m. showed that germination decreased by one-third from 62 percent directly after treatment to 41 percent *(table 2)*. At 200 and 500 p.p.m. gibberellic acid (soaking for 1 hour) germination remained practically unchanged before and after 4 months' storage. But after the same treated seed had been refrigerated for 11 months, tests showed that both concentration and soaking period affected seed germination. The highest germination (58 percent) after storage resulted from seed that had been treated at 500 p.p.m. for 4 hours, for a net increase of nearly 50 percent, whereas at 100 p.p.m. for all soaking periods and at 200 and 500 p.p.m. for 1/2 hour, germination decreased from 23 to more than 50 percent after seed was stored *(table 2)*. Practically no differences in germination percentages occurred before and after storage for seed treated with 200 p.p.m. for 1 and 4 hours, or 500 p.p.m. for 1 hour.

Excised embryos germinated the quickest, averaging 7 days. Germination time for all gibberellic acid soak and stratified seed averaged 8 to 10 days. Untreated and gibberellic acid-slurry treated seed averaged 19 to 21 days. Gibberellic acid-soaked seed and excised embryos started to germinate within 3 to

Table 1–*Germination of creeping sage seed tested directly after treatment, by type of treatment*

Treatment	Germination
	Percent
Soaking in gibberellic acid at 100 p.p.m. for:	
1/4 hour	[1]33 b
1/2 hour	46 bc
1 hour	62 d
4 hours	48 bc
200 p.p.m. for:	
1/4 hour	50 bcd
1/2 hour	48 bc
1 hour	39 b
4 hours	44 bc
500 p.p.m. for:	
1/4 hour	50 bcd
1/2 hour	55 cd
1 hour	46 bc
4 hours	39 b
Gibberellic acid slurry	53 cd
Stratified 3 months:	
Without gibberellic acid	54 cd
With gibberellic acid[2]	50 bcd
Excised embryos	[3]70
Control	3 a

[1]Values followed by same letters do not differ significantly at 5 percent level, as determined by Duncan's Multiple Range Test.

[2]Concentration of 500 p.p.m. for 1/4 hour.

[3]Statistical significance not determined.

Table 2–*Germination in 30 days of creeping sage treated with gibberellic acid–before storage and after storage of 4 and 11 months.*

Concentration and soaking period	Before storage	After storage		Difference	
		4 months	11 months	4 months	11 months
	Percent				
100 p.p.m.:					
1/2 hour	46	–	24	–	-22*
1 hour	62	41	30	-21	-32*
4 hours	48	–	28	–	-20*
200 p.p.m.:					
1/2 hour	48	–	28	–	-20*
1 hour	39	38	42	-1	+3
4 hours	44	–	40	–	-4
500 p.p.m.:					
1/2 hour	55	–	42	–	-13
1 hour	46	46	44	0	-2
4 hours	39	–	58	–	+19*

*Statistically significant at 5 percent level of probability.

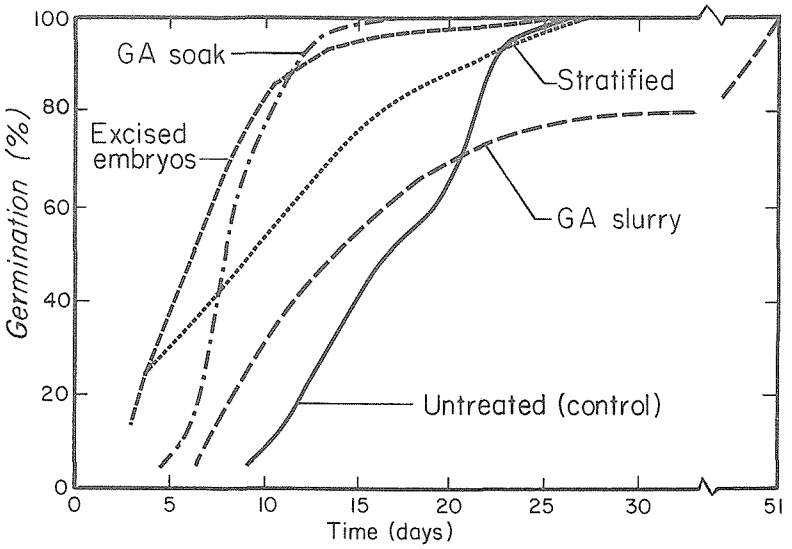

Figure 2—*Applications of gibberellic acid soaking or slurry helped speed up rate of germination in creeping sage seed. Soak line represents averages for all concentrations and soaking periods used and seed tested directly after treatments.*

4 days, and more than 90 percent of total germination occurred within 12 days *(fig. 2).* Stratified seed started to germinate about the same time, but then slowed down and continued over a longer period than either the excised or gibberellic acid-soaked seed, requiring 21 days for 90 percent of total germination to take place. Germination of gibberellic acid-slurry required 24 days and untreated seed required 51 days for 90 percent of total germination.

Neither gibberellic acid concentration nor soaking time had much effect on speed of germination. We found practically no differences in speed of germination, which ranged from 8 to 10 days before and after storage for seed treated with 500 p.p.m. for 1/2 to 4 hours, or at 200 p.p.m. for 4 hours. But germination was 2 to 4 days slower after storage for seed treated at 100 or 200 p.p.m. for 1 hour or shorter soaking periods.

DISCUSSION AND CONCLUSIONS

The main barrier to germination of creeping sage seed appears to be chemical agent rather than a physical restriction in the seed coat or embryo dormancy. Evidence of chemical inhibition was the higher and more rapid germination when embryos were excised and seed coats were completely removed. The specific inhibitory agent and the effect it might have on germination were not determined.

To be most effective gibberellic acid should be applied in a form and for a sufficient period to penetrate the integument on the seed. This condition was evident from the highly significant (1 percent level) interaction between acid concentration and storage, and significant (5 percent level) interaction between soaking period and storage upon germination percentages of creeping sage seed that had been soaked for various periods at different concentrations.

The average time to germinate was nearly the same before or after storage for seed treated at the higher concentrations and longer soaking periods. But it required stored seed treated at either lower concentrations or shorter soaking periods 2 to 4 days longer to germinate than seeds that had not been stored.

A portion of gibberellic acid remains as a salt covering on the surface of treated seed that is air-dried. Under conditions of the tests, this acid was still available to go back into solution and be adsorbed by the embryo when seed was placed to germinate on moistened blotters. When seed was treated and stored for several months, gibberellic acid remaining on the seed apparently deteriorated and could not break dormancy and stimulate germination when other conditions were favorable. Similar conditions may also occur when treated seed is planted where soil becomes excessively wet. Gibberellic acid not previously adsorbed but retained on the seed coat surface is leached away so seed remains dormant.[3] Distilled water was added as needed to keep the blotters moist. Gibberellic acid deteriorates when stored for any period, especially when in solution or when moisture is present. The half-life of dilute solutions of aqueous gibberellic acid is of the order of 14 days at 78°F., and more rapid at higher temperatures.[3]

Treat creeping sage seeds, preferably only a few days in advance of plantings, by soaking them in gibberellic acid that is constantly agitated and air-dry them thoroughly. Do not rinse or wash seeds. A

1-hour soak in 100 p.p.m. gibberellic acid is satisfactory if seeds are sown within a few days after treatment on areas where soil moisture conditions may be carefully controlled after plantings, such as in the nursery or greenhouse. If plantings may be delayed for more than about 10 days after seed are treated and soil moisture conditions are unpredictable, use stronger solutions and longer soaking periods—probably up to 500 p.p.m. for periods up to 4 hours or longer to reduce risks of leaching should rains occur before seed germinates.

Higher as well as faster total germination resulting from gibberellic acid soak treatment should facilitate sowing by conventional equipment and enable establishment of creeping sage seedling stands to compete with other vegetation—especially on sites where soil moisture conditions may be critical in spring.

NOTES

[1]Mirov, N. T., and C. J. Kraebel. *Collecting and handling seeds of wild plants.* U.S. Forest Serv. Civilian Conserv. Corp. Forest Publ. 5. 42 p. 1939.

[2]Commercial enterprises or products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

[3]Anonymous. *'Berelex' (gibberellic acid).* Cambridge, England: Plant Protection Ltd. 38 p. 1969.

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