Where there's smoke... THERE'S GERMINATION?

Thomas D Landis

Downloaded from by guest on April 19, 2024. Copyright 2000

Unlike seeds of horticultural crops, which have been bred to germinate immediately after sowing, those of many native plant species become dormant after they mature. Seed dormancy is defined as the physiological state in which otherwise viable seeds will not germinate even when exposed to growth-conducive conditions. Seed dormancy has intrigued biologists and frustrated horticulturists for many years. Native plant growers are less interested with the "why" than the "how" of seed dormancy and have traditionally looked to nature when trying to get stubborn seeds to germinate. The practice of seed stratification is a good example. By storing seeds in moist media in a refrigerator, growers are imitating the natural cold and moist overwinter environment.

Abstract

Seeds of many fire-adapted plants are very difficult to germinate, and some species have been impossible to propagate by seed. Recent research has shown that fumigating seeds with smoke or soaking them in smoke solutions improves germination of many species. The exact physiological mechanism for this response is unknown but using smoke as a pre-sowing seed treatment holds considerable promise for propagating plants for restoration of fire-adapted communities. In particular, smoke treatments can be used to germinate seeds of recalcitrant species. This paper reviews the current literature on smoke treatment of seeds with the purpose of encouraging these treatments on other species.

KEYWORDS: seed treatment, native plants, nursery, seedlings, restoration

NOMENCLATURE: (North American species) ITIS (1998)

Seed Treatments Related to Fire

Seeds of some native plants do not respond to stratification, however, and so seed biologists have investigated other ways of getting them to germinate. One intriguing example concerns fire-adapted species. Plant communities, like the chaparral of California or the fynbos of South Africa, are so adapted to fire that many species can only reproduce when aided by either heat or chemical products of combustion. A number of research studies in the past 10 y have lead to some innovative treatments for seeds of fire-adapted species: dry heat, ash, charred wood, burned soil, and smoke (Figure 1).

Dry Heat

In laboratory studies, exposing seeds to temperatures of 70 to 150 °C (158 to 302 °F) for 1 to 120 min has promoted seed germination of over 40 species (Baskin and Baskin 1998). Under nursery conditions, however, dry heat is seldom recommended for overcoming seed dormancy because of the danger of embryo damage. And, because seeds are covered with soil, it is difficult to control the temperature around the seeds. A few nursery manuals have published dry heat treatments. One treatment involves sowing seeds of eucalypts (Myrtaceae) in germination flats and covering them with 6 mm (0.25 in) of soil, topped with a layer of straw. The straw is then ignited and allowed to completely burn, and the dry heat breaks down the seed coat (Macdonald 1986). Fire has also been used on the seeds of some woody shrubs (for example, manzanita [Ericaceae]) from Southern California (Emery 1988). In general, however, heat has been less effective than charred wood or smoke treatments (Figure 1).

TABLE 1

Western US species that responded favorably to smoke seed treatments

Big sagebrush	*Artemesia tridentata* Nutt. (Compositae)
Antelope bitterbrush	*Purshia tridentata* (Pursh) DC (Rosaceae)
Basin wildrye	*Leymus cinereus* (Scribner & Merr.) A. Love (Poaceae)
White pincushion	*Chaenactis artemisiifolia* (Harvey & Gray ex Gray) Gray (Asteraceae)
White sage	*Salvia apiana* Jepson (Lamiaceae)
Scarlet bugler	*Penstemon centranthifolius* Benth. (Scrophulariaceae)

Source: Blank and Young (1998); Keeley and Fotheringham (1998a).

Ash, Charred Wood, and Burned Soil

Ash treatments have been tried with seeds of several species with marginal results. For example, Reyes and Casal (1998) found that both aqueous ash solutions and direct ash treatments did not positively effect the germination of *Pinus pinaster* Aiton (Pinaceae), *Pinus radiata* D. Don, or *Eucalyptus globulus* Labill. (Myrtaceae). Better results have occurred using an aqueous extract from charred wood (charate). Charate has promoted improved germination of the seeds of over 50 species from 6% to 82% compared to controls, but has no stimulatory effect on some seeds and actually decreases germination in others (Baskin and Baskin 1998). When an aqueous leachate of charred wood was used to treat seeds of California chaparral plants, the results were variable but always less effective than smoke treatments (Figure 1). In another study, an aqueous extract of heated soil increased the germination and growth of grass and brush species of sagebrush communities in the western US (Blank and Young 1998). However intriguing these results may be, attempts to use ash or charred wood extracts to promote seed germination in operational nursery trials or in the field have proven unsuccessful (Baskin and Baskin 1998).

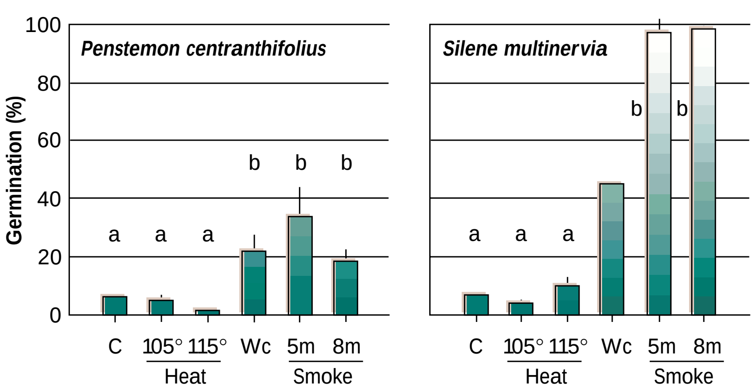

Figure 1 • Treating seeds of fire-adapted plants with smoke treatments of 5- or 8-min exposures was more effective than charred wood (Wc), heat exposure at 2 different temperatures (°C), or the control (C). Bars with the same letter are not significantly different (P = 0.05); those without a letter are significantly different from those with letters. (Modified from Keeley and Fotheringham 1998a).

Smoke

Smoke treatments were first demonstrated to stimulate seed germination of a fire-adapted shrub in South Africa (De Lange and Boucher 1990), but have recently been demonstrated for plants of other fire-adapted communities in Australia (Dixon and others 1995) and the western US (Table 1). Smoke from the combustion of plant materials has positively affected germination of 170 different native plants representing 37 families and 88 genera (Roche and others 1997). The potential for smoke treatment extends beyond fire-adapted species, however. Smoke has even been used to break dormancy and improve

Downloaded from by guest on April 19, 2024. Copyright 2000

germination of seeds of common vegetables such as lettuce and celery (Brown and Van Staden 1998).

Although the strength of the response varies, it is very impressive with many species (Figure 2). Of particular interest to native plant growers, many taxa of plants that respond to smoke treatment are considered "difficult to germinate" and some have been totally unresponsive to conventional seed propagation techniques. Another intriguing result is that the stimulatory effect may continue beyond seed germination for some plants. Native grass seeds that were treated with smoke extracts grew better than the controls and produced significantly greater biomass after 4 mo (Blank and Young 1998).

Considerable effort has gone into trying to determine the chemical basis for smoke treatment of seeds. Keeley and Fotheringham (1998b) could not substantiate the hypothesis that nitrate produced from wildfires is responsible for the increased germination but did find that oxidizing gases, such as nitrogen dioxide, and acids were involved. The probability is that more than one factor is responsible, and besides, nursery managers are less interested in the exact mechanism of why smoke treatments work than they are about how to use them operationally.

Downloaded from by guest on April 19, 2024. Copyright 2000

Smoke Treatments

The method of treating seeds with smoke has undergone continual modification, but two basic application techniques, smoke fumigation and smoke water, have been used.

Smoke Fumigation

The first experiments used an "aerosol smoke" generated from burning a mixture of dry and fresh vegetation and fumigating soil in the wild or seeds sown in trays. In Australia, smoke from an external combustion chamber was piped into specially constructed smoke tents that contained screen trays of seeds or propagation trays of seeds sown in soil (Figure 3). The combustion chamber consisted of a metal drum fitted with intake and exhaust pipes, with air pumped through at a rate of 100 to 300 l/min. A typical fumigation treatment lasted 60 min, and then seeds were either sown or kept under dry storage (Dixon and Roche 1996).

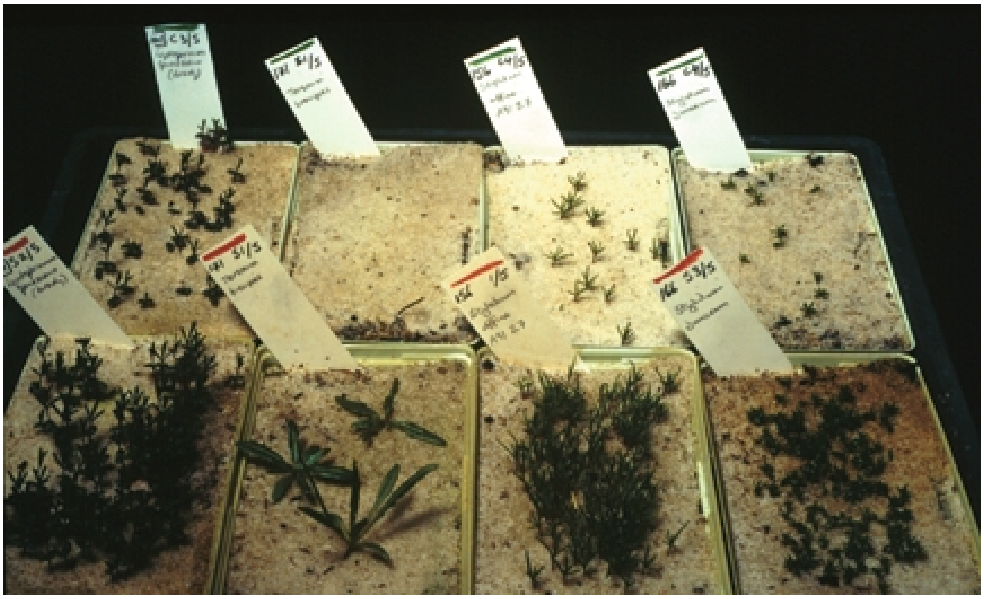

Figure 2 • Considerable research with smoke treatments has been done in Australia where treated seeds (foreground) have better germination than controls (background). Left to right: Leptospermum spinescens *Endl. (Myrtaceae);* Tersonia cyathiflora *(Fenzl) J.W. Green (Gyrostemonaceae);* Stylidium affine *Sond. (Stylidiaceae);* Stylidium junceum *R. Br. (Stylidiaceae). (Courtesy of Dr Kingsley Dixon, Director Plant Sciences, Kings Park and Botanic Gardens, West Perth 6005, Western Australia).*

Smoke Water

The active ingredient in aerosol smoke was found to be soluble in water, so the next improvement was to create an aqueous smoke solution. Bubbling smoke from burning vegetation through distilled water created an aqueous smoke extract that was then used to treat seeds. For example, Tieu and others (1999) burned 6 kg (13.3 lb) of branches and foliage in a combustion chamber and pumped the exhaust through a 20-l (5.3-gal) tank of water for 60 min. Seed is soaked for 12 h in a 10% solution of the smoke water concentrate, or the stock solution can be frozen for later use (Dixon and Roche 1996). The latest development is that seeds can be imbibed with aqueous smoke solution and then dried for later sowing. With some wildflower species, smoke-treated seeds retained their enhanced germination after a year of dry storage (Brown and Van Staden 1998).

Practical Application of Smoke Treatment of Seed

Other seed treatment considerations include traditional seed pretreatments, the kind of plant material burned, combustion temperature, response of treated species, and commercial availability of smoke products.

Pretreatments

Seeds of some plants respond to the smoke when dry whereas others need to be presoaked in water. Sometimes, traditional seed treatments such as mechanical or acid scarification or storage in soil increase the efficacy of the smoke treatments (Roche and others 1997).

Type of Plant Material

The type of combustion material has varied from sawdust to fresh and aged tissue of grass, brush, and tree

Figure 3 • *Tent for smoking sown seed trays or direct smoke application to field soil. Soaking seeds in aqueous smoke solutions is the newest and most practical treatment. (Courtesy of Dr Kingsley Dixon, Director Plant Sciences, Kings Park and Botanic Gardens, West Perth 6005, Western Australia).*

Downloaded from by guest on April 19, 2024. Copyright 2000

species. Using branches and foliage of native species is usually preferred because their combustion would simulate the natural smokes produced by wildland fires. However, the chemical composition of smoke may vary between different plant species and perhaps between types of tissue within a species. On the other hand, the active ingredient may be generic because tissue paper and commercial smoke flavoring products have even been effective (Brown and Van Staden 1997).

TABLE 2

Germination of seeds of a South African wildflower (Syncarpha vestita *(L.) B. Nord. [Asteraceae]) varied with concentration of smoke water*

Smoke water extract dilutions	Germination (%)
Control (water)	5
1:5000	58
1:500	66
1:50	78
1:5	85
1:2	25

Source: Brown and Van Staden (1997).

Combustion Temperature

The chemical composition of smoke varies with temperature but tests indicate that activating compounds produced between 160 and 200 °C (320 to 392 °F) are the most active (Jager and others 1996). Apparently, the stimulatory chemicals are lost through volatilization at higher temperatures. So, on a practical basis, a slow smoldering fire will be most effective (Brown and Van Staden 1997).

Species Response

The effect of smoke is highly variable and affects species and ecotypes differently (Dixon and Roche 1996). Highly concentrated smoke water solutions may inhibit germination of some species, so growers will need to experiment with different dilutions to get the best effect (Table 2). Indeed, considering the variation in chemical composition between burning various plant tissues and species and the concentration of these chemicals at various dilutions, careful experimentation and accurate record keeping will be necessary before operational treatments can begin.

Commercial Smoke Products

Two commercial seed treatments are now available. "Kirstenbosch Instant Smoke Plus" is a patented seed primer developed at the National Botanical Institute in Cape Town, South Africa. This seed primer is made using aqueous smoke extracts that are dehydrated and sold in packet form. Another product called "Seed Starter-Australian Smoky Water" is available from the Friends of Kings Park and Botanic Garden in Perth, Western Australia. Both seed treatments tested favorably when compared to an aqueous smoke extract and a water control (Brown and Van Staden 1997).

Standardizing Smoke Treatments

Although fascinating, the entire process of treating seeds with smoke water is rife with uncontrolled variation. The type of plant material, the combustion temperature, and the dilution of the smoke water all introduce so much variability that it is difficult to reach many conclusions. This should not detract from the operational use of smoke to treat small lots of native plant seeds but, in order to reproduce their results, growers must standardize their procedures and keep good detailed records.

Besides nursery trials, controlled research using a standardized plant material and combustion technique is needed if the smoke water treatment can ever be used for large scale production. For example, a down-draught gasifier, which burns wood chips to produce gas for internal combustion engines, has been used to test the smoke water treatment on crop seeds. This research demonstrates that biologically active substances generated from willow wood chips are heat stable (Thornton and others 1999). Using such standardized procedures, smoke water dilutions of known concentration can be developed and tested in replicable experiments.

Conclusions and Recommendations

Treating native plant seeds with smoke is an intriguing option for native plant growers. Not only is this "natural" seed treatment intuitively obvious for fire-adapted plants, but tests have shown that it is effective for other species as well. Soaking seeds in smoke water is the most practical application because large quantities of seed can be quickly and easily treated. However, because of the tremendous amount of inherent variation in the procedure, smoke treatment of seeds must be investigated under both operational nursery and controlled research conditions. For nursery tests, an aqueous smoke extract can be easily produced and then seed germination can be tested against a range of dilutions. Controlled research is also needed using a standardized combustion technique and plant materials. In either case, diligent attention to detail and careful record keeping will be necessary. Government research facilities and nurseries could provide a good technology transfer service if they would investigate smoke seed treatments for local species and share their results at nursery meetings and in trade journals.

Downloaded from by guest on April 19, 2024. Copyright 2000

References

Baskin CC, Baskin JM. 1998. Seeds: ecology, biogeography, and evolution of dormancy and germination. New York (NY): Academic Press. 666 p.

Blank RR, Young JA. 1998. Heated substrate and smoke: influence on seed emergence and plant growth. Journal of Range Management 51:577–583.

Brown NAC, Van Staden J. 1997. Smoke as a germination cue: a review. Plant Growth Regulation 22:115–124.

Brown NAC, Van Staden J. 1998. Plant-derived smoke: an effective seed pre-soaking treatment for wildflower species and with potential for horticultural and vegetable crops. Seed Science and Technology 26(3):669–673.

De Lange JH, Boucher C. 1990. Autecological studies on *Audouinia capitania* (Bruniacease). I. Plant–derived smoke as a seed germination cue. South African Journal of Botany 56:700–703.

Dixon KW, Roche S, Pate JS. 1995. The promotive effect of smoke derived from burnt native vegetation on seed germination of western Australian plants. Oecologia 101:185–192.

Dixon KW, Roche S. 1996. The role of combustion products (smoke) in stimulating *ex situ* and *in situ* germination of western Australian plants. The International Plant Propagators' Society, Combined Proceedings 45:53–56.

Emery DE. 1988. Seed propagation of native California plants. Santa Barbara (CA): Santa Barbara Botanic Garden. 115 p.

[ITIS] Integrated Taxonomic Information System. 1998. Biological names. Version 4.0 (on-line database). URL: http://www.itis.usda.gov/plantproj/itis/itis_query.html (updated 15 December 1998).

Jager AK, Light ME, Van Staden J. 1996. Effects of source of plant material and temperature on the production of smoke extracts that promote germination of light-sensitive lettuce seeds. Environmental and Experimental Botany 36:421–429.

Keeley JE, Fotheringham CJ. 1998a. Smoke-induced seed germination in California chaparral. Ecology 79: 2320–2336.

Keeley JE, Fotheringham CJ. 1998b. Mechanism of smoke-induced seed germination in a post-fire chaparral annual. Journal of Ecology 86:27–36.

Macdonald B. 1986. Practical woody plant propagation for nursery growers. Volume 1. Portland (OR): Timber Press. 669 p.

Reyes O, Casal M. 1998. Germination of *Pinus pinaster*, *P. radiata* and *Eucalyptus globulus* in relations to the amount of ash produced in forest fires. Annales des Sciences Forestieres 55:837–845.

Roche S, Dixon KW, Pate JS. 1997. Seed aging and smoke: partner cues in the amelioration of seed dormancy in selected Australian native species. Australian Journal of Botany 45:783–815.

Thornton MA, Thomas TH, Peters NCB. 1999. The promotive effect of combustion products from plant vegetation on the release of seeds from dormancy. Plant Growth Regulation 28:129–132.

Tieu A, Dixon KA, Sivasithamparam K, Plummer JA. 1999. Germination of four species of native western Australian plants using plant-derived smoke. Australian Journal of Botany 47:207–219.

Author Information

Thomas D Landis
National Nursery Specialist
USDA Forest Service
JH Stone Nursery
2606 Old Stage Road
Central Point, OR 97502
nurseries@aol.com