The Effects of Fire on Seed Germination[1]

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Highlight

Fire is characteristically used in the pineywoods of the Southeast to produce repetitive abundant stands of native legumes. However, results are frequently erratic and unpredictable. Seed germination results following simulated fire conditions are presented. Results show dry heat ineffective in increasing germination, whereas moist heat greatly increased both germination rate and total germination of some species of seed.

Terms such as "fire climax" and "fire species" have been used to describe plant communities in the Southeastern part of the United States for a long time. Probably one of the best known "fire communities" is the pine–wiregrass–legume association common in the Georgia–Florida flatwoods.

Although the use of fire as a land management tool has undergone periods of severe criticism—sometimes justifiable—the last 20 to 30 years of research have made necessary a rather drastic reorientation of our ideas about fire as an ecological factor. Odum (1953) stated: "It is now evident that fire should be considered not a minor or abnormal factor but a major factor which in many regions is, and has been for centuries, almost a part of the normal climate." Classic works concerning the ecological effects of fire are those by Ahlgren in Minnesota; Biswell and Sampson in California; Bruce, Chapman, Garren, Stoddard, Green, and Wahlenberg in the South; Weaver in the Ponderosa country of the West; Lutz in Alaska; and Little in the pine barren region of New Jersey, plus many others. However, references dealing with the specific effects of fire on such a basic part of the plant kingdom as a seed are few.

The authors have to date found works by Hofmann (1925), Wright (1931), Stone and Juhren (1951), and Went et al. (1952) concerning the effects of fire on seed of woody species. There is a definite lack of published information on the effects of fire on the germination of seed from the native herbaceous plants which are so vital to our southeastern range and wildlife resources. Therefore, in 1964, the Forest Service, cooperating with the Virginia Polytechnic Institute and the International Paper Company, began a program of research to determine the effects of fire on several of the more important range and wildlife food plants found in the Southeastern Coastal Plain flatwoods, with particular emphasis on *Cassia nictitans* and *C. fasciculata*.

Recently, Martin and Cushwa (1966) presented results from laboratory experiments concerning the effect of heat and moisture on native legume seed germination. The present report uses this material for background information, and summarizes results from current experiments.

Field Conditions

Let us review "normal" field conditions and some possible effects of fire on seed, as stated by Martin and Cushwa (1966). Generally, burns conducted specifically for the purpose of increasing legume flora are done in open stands of slash and longleaf pine shortly after a rain, when the surface fuel will readily carry fire and the lower fuel layers are still quite moist (Stoddard, 1931, 1961).

With this in mind, we might consider several possible effects of fire in bringing about a regeneration of these plants. First, the effect might be considered as a manipulation of growing conditions. This could be merely an improved seedbed that allows the seed a better chance to germinate and root in a favorable mineral soil. Second, the effect could be to change the environment of the seed or plant chemically. A third possibility would be changes in the biotic environment, either by reducing competition for light, nutrients, and water; or by inhibiting factors exuded from organisms; or by reducing seed and seedling destruction by various organisms. A fourth possibility could be the direct effect of fire on the seed—that is, changing the temperature and moisture conditions of the seed during the fire.

We know, for example, that temperatures in the upper soil layers during prescribed burns in the "pineywoods" of the South rarely exceed 300 F and that the increased temperature is of short duration, being in the range of from 2 to 4 minutes (Heyward, 1938).

Moisture conditions in litter and upper soil layers during prescribed burns in this pine ecosystem are not available. However, one could speculate that because water is one of the main products of thermal degradation and combustion of woody fuels (Uggla, 1958), and because burning is usually done when subfuels are moist, some water vapor produced from either of these sources could be expected to diffuse downward due to vapor pressure gradients and condense on cooler objects, such

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as a seed, thus changing both the temperature and moisture conditions of the seed. At least part of the legume seed population stored in the fuel and upper soil layers are "macrobiotic" hard seed (Rampton and Ching, 1966) which, because of either physical or physiological dormancy, are viable but have not and will not germinate until conditions are altered. The condition of hard seed in legumes in general is widely recognized (Mayer and Poljakoff-Mayber, 1963; Fordham, 1965; Kawatake et al., 1955; Koller and Neghi, 1966; Amen, 1963), but not well understood; however, generally a physiological dormancy would be a factor within the embryo itself, whereas a physical dormancy would be a factor within the seedcoat. Also, it may be possible for a seed to have both physiological and physical dormancy, and the embryo and seedcoat may be intermingled in dormancies.

Assuming that high temperatures during a fire actually break dormancy or increase the rate of germination or overall germination, generally at low temperatures a given species of seed would have a relatively constant germination percentage. As temperature is increased, a range would finally be encountered where dormancy factors were broken, resulting in an increase in germination percentage. Following this, as temperature continues to increase, a plateau of relatively constant high germination would be expected, and finally there is a rather sharp decrease until no germination whatever occurs because of the lethal effects of high temperatures. We might otherwise state the null hypothesis as—no increased germination occurs due to increasing temperature.

Cassia nictitans was the species used in our early experiments for several reasons. First, it is one of the more important quail food plants in the Southeast (Stoddard, 1931), and therefore, knowledge of fire effects on this seed would be most useful in prescribing proper burning conditions. Second, the wide distribution and abundance of this plant reduces the problem of obtaining experimental material. Third, it is an annual plant and therefore depends entirely on seed as a means of propagation. Fourth, it produces hard seed which remain dormant and viable for long periods of time.

Table 1. Average response (percent germination) of *Cassia nictitans* seed to different treatments.

Treatment	Age of seed: Collected fall 1963; tested summer 1965	Collected fall 1965; tested winter 1966	Collected fall 1965; tested summer 1966
Control (no treat.)	58	12	44
Soaked in H_2SO_4, 25 min	99	—	71
Soaked in H_2O at 70°C, 30 min	95	—	93
Mechanical abrasion	92	—	77
Dry Heat (Temp. °C)			
45	35	9	9
60	—	7	11
70	—	5	19
80	38	7	26
90	32	24	19
100	3	27	0
110	0	0	0
Moist Heat (Temp. °C)			
45	—	6	39
60	78	15	85
70	86	34	98
72.5	—	—	97
75	—	80	96
77.5	—	92	98
80	93	99	95
82.5	—	98	96
85	—	98	94
90	39	96	74
92.5	—	—	43
95	—	—	1
98.4	2	45	2

Methods and Results

Our first experiments involved four minutes exposure of *Cassia nictitans* seed to different temperature treatments in the dry atmosphere of a modified laboratory oven. These treatments had no significant effect on germination (Table 1). Also, germination was usually eliminated by four minutes exposure to dry heat treatments above 100 C.

Next, we scarified seed by soaking them in concentrated sulfuric acid for 25 minutes at room temperature and others in water to 70 C for 30 minutes. We also mechanically scarified seed by rubbing them with sandpaper. Seed exposed to these three treatments exhibited increased germination. Therefore, it follows that germination was enhanced by scarification, possibly by increasing the permeability to water and gases. It would seem possible that fire might affect dormancy by altering the seedcoat chemically, as in the acid treatment, or physically, through dissolution or hydration as might have occurred in both the acid and hot-water treatments. Either of these treatments would have affected the outer-most layer of the seedcoat, the same layer affected by mechanical scarification.

In order to determine if fire affected the seedcoat chemically, some seed were placed in ashes from pine-needle fires and others were moistened with water percolated through these ashes. Neither of these treatments, however, resulted in any increased germination, indicating that a chemical scarification could not be expected from fire.

Seed heated at 80 C in an atmosphere saturated with water vapor exhibited an extremely high germination rate and cumulative germination—up to 75% germination 3 days after treatment and greater

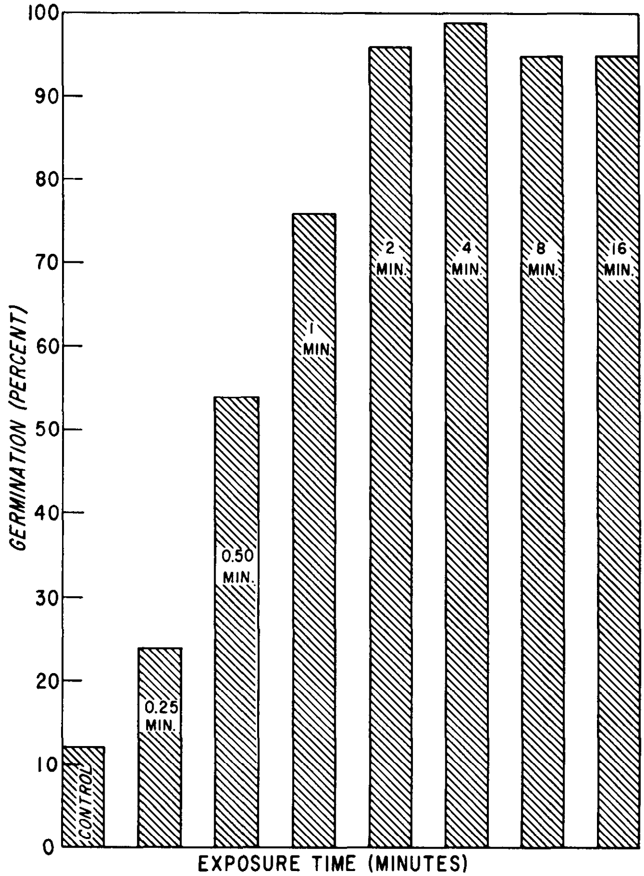

FIG. 1. Effect of varying time in a saturated atmosphere at a constant temperature of 80 C on germination of *Cassia nictitans* seed.

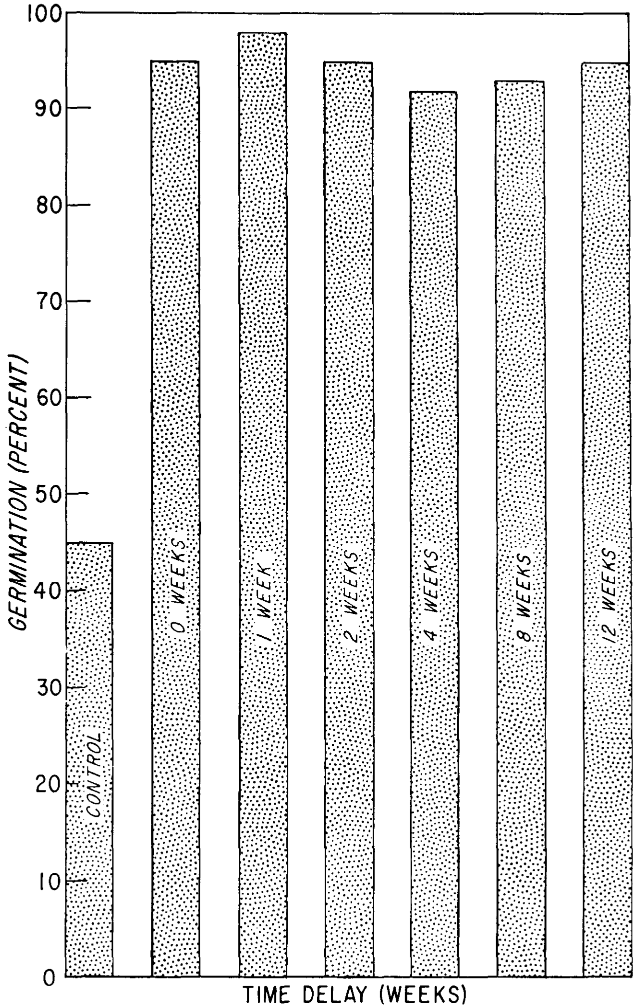

FIG. 2. The effect on germination of withholding moisture for varying time periods after *Cassia nictitans* seed were exposed to a moist-heat treatment at 80 C for four minutes.

than 95% cumulative germination. In all succeeding experiments, *Cassia nictitans* seed responded to the moist-heat treatments, the degree of response depending on seed population, age, temperature, and duration of treatment, and post-treatment delay (Table 1 and Fig. 1 and 2). There is a tendency for germination rate following moist-heat treatment to increase with the age of the seed, but cumulative germination does not change appreciably (Table 1).

In order to see how period of exposure to temperature treatments affected germination rate, we used moist heat at 80 C and varied the period from 15 seconds to 16 minutes. Cumulative germination increased with heating time up to 2 minutes, with no decrease for 16 minutes exposure. Germination rate increased for heating times up to 4 minutes exposure, but remained relatively constant for longer exposures (Fig. 1).

What is the effectiveness of moist-heat treatments if, following a fire, seed remain dry for various periods of time before sufficient moisture for germination is available? We withheld moisture up to 12 weeks following treatment, allowing seed to dry in the laboratory. The greatest effect was an increased *rate* of germination in the first three to seven days following wetting. This was noticeable up to an 8-week delay; 12-weeks' delay, however, seemed to decrease the early germination rate. There were no apparent differences in cumulative germination whether or not a delay period was used (Fig. 2).

The effects of hot water and a saturated atmosphere on seedcoat appearance have been demonstrated by light microscopy. Not only is the overall seedcoat appearance altered, but there are also striking changes in pre-treatment "dimpled" areas of the seedcoat; following treatment, these stand out as "elevated dimples." This suggests that some of the seedcoat material was removed during treatment. Exposing seed for four minutes in water at 80 C removed a highly hydrated material that had about the same volume as the seed, but amounted to only slightly over three % of the total dry weight of a seed. This material can be precipitated by ethyl alcohol. Although its exact nature is not

Table 2. Average response (percent germination) of legume seed treated during the winter 1966–67.

Species	Control No Treatment	Moist heat (Temperature °C)						Dry heat (Temperature °C)						
		45	60	70	80	90	98	45	60	70	80	90	100	110
*Lespedeza intermixta**	73	75	76	78	42	4	0	83	78	80	86	68	3	0
*Lespedeza daurica**	36	33	49	56	56	0	0	41	42	39	49	63	0	–
*Lespedeza cyrtobotrya**	27	59	72	87	69	19	1	63	83	83	84	89	0	0
*Lespedeza cuneata**	88	86	85	91	27	0	0	93	83	90	89	83	2	0
*Lespedeza virgata**	59	65	61	40	34	1	0	59	60	63	60	57	0	0
*Lespedeza japonica**	80	85	87	88	56	0	0	85	88	89	93	91	0	0
Lespedeza daurica var. *schimidae**	56	57	63	78	66	1	0	58	58	67	71	71	0	0
*Lespedeza capitata**	70	76	76	75	65	3	1	79	78	80	77	79	0	0
*Lespedeza hedysaroides**	40	31	56	69	60	0	1	35	49	58	72	86	0	0
*Lespedeza tomentosa**	31	30	51	48	25	4	0	30	53	61	50	63	0	0
*Lespedeza bicolor**	64	62	68	69	35	0	1	65	69	68	66	54	0	0
Cassia aspera	34	39	40	44	44	67	24	38	37	38	42	37	20	0

* Seed supplied and identified by Dr. A. F. Clewell, Assistant Professor of Botany, Florida State University, Tallahassee, Florida.

known, Tookey and Jones (1965) indicated that the seed of *Cassia fasciculata* contain 23% galactomannans. From the *Cassia nictitans* seedcoat material we removed, preliminary results indicate a molecular weight of about 200,000 by gel filtration and 17,000 to 100,000 by ultracentrifuging, depending on assumptions of the molecular configurations. The structure of the molecule, as well as the basic carbohydrate units, has yet to be determined.

Discussion

So far our results have some puzzling aspects. For example, *Cassia aspera*, a species closely resembling *Cassia nictitans* but confined to the more temperate environment of South Florida, responded relatively well to temperature treatments (Table 2). However, *Cassia fasciculata*, which commonly grows with *Cassia nictitans* but is confined to more open situations, has responded poorly to moist and dry heat treatments. Foote and Jackobs (1966) reported no difficulty in obtaining germination of seed from this species collected in Illinois. Because our heat treatments failed to induce germination of *Cassia fasciculata* seed, we are now testing the effect of stratification on germination. Recently, we exposed *Cassia fasciculata* seed to a temperature of 2 C for one week in a refrigerator, and then exposed these stratified seed to a moist-heat treatment for four minutes at 80 C. Results look promising; seven days following both stratification and scarification treatments, seed were germinating.

We have also conducted experiments to determine the effect of temperature treatments on the germination of 13 species of *Lespedeza*, 3 species of *Desmodium*, and 1 species of *Galactia* (Tables 2 and 3), all of which are common plants in the fire ecosystem of the Southeast.

Recently, we exposed palmetto (*Serenoa repens*) and razorsedge (*Scleria muhlenbergii*) seed to a variety of moist and dry temperature treatments plus mechanical abrasion and acid treatments. To date we have been unable to obtain any germination. Hilmon[2] (personal correspondence 1967) obtained germination of palmetto seed by two

[2] Range Scientist, U.S.D.A., Forest Service, Southeastern Forest Experiment Station, Fort Myers, Florida.

Table 3. Average response (percent germination) of legume seed treated during the summer of 1966.

Species	Control No Treatment	Moist heat (Temperature °C)						Dry heat (Temperature °C)						
		45	60	70	80	90	98	45	60	70	80	90	100	110
Cassia fasciculata	0	1	1	1	2	3	0	1	0	0	1	1	0	0
Desmodium ciliare	97	97	100	100	75	0	0	97	97	97	70	4	0	0
Desmodium cuspidatum	76	72	69	77	81	29	0	73	79	79	78	20	0	0
Desmodium fernaldii	91	90	90	91	92	26	0	88	89	91	91	15	0	0
Galactia volubilis	12	4	16	16	16	32	12	20	12	16	24	8	0	0
*Lespedeza bicolor**	4	44	76	68	92	84	88	44	68	80	100	100	0	0
*Lespedeza hirta**	4	6	7	7	18	32	15	3	3	6	10	51	0	0
Lespedeza hirta var. *curtissii**	2	5	3	4	16	7	0	1	2	3	17	3	0	0

* Seed supplied and identified by Dr. A. F. Clewell, Assistant Professor of Botany, Florida State University, Tallahassee, Florida.

methods: (a) By removing the micropyle cover and exposing the endosperm to moisture, and (b) by increasing the oxygen pressure. Also, he was able to germinate *Scleria* seed taken from quail crops.

In summary, our work is still in the developmental stages. Nonetheless, we feel that we have been able to create a situation in the laboratory which closely resembles field burning conditions. But we have not been able to prove this, mainly because of the complexity of the time, temperature, and moisture relationships during a burn.

We have installed a field study designed to bracket these variables, and hopefully we will emerge with an evaluation prescription for conditions which will enable a land manager to manipulate vegetation through the use of fire. In addition, we are examining the chemical composition and physical structure of seedcoat materials in order to understand better the role of fire in propagating these species.

LITERATURE CITED

AHLGREN, I. F., AND C. E. AHLGREN. 1960. Ecological effects of forest fires. Bot. Rev. 26:483–533.

AMEN, R. D. 1963. The concept of seed dormancy. Amer. Sci. 51(4):408–424.

BISWELL, H. H. 1963. Research in wildland fire ecology in California. 2nd Tall Timbers Fire Ecol. Conf. Proc., p. 63–97.

BRUCE, D. 1959. Effect of low competition on longleaf pine seedling growth. Soc. Amer. Forest. Proc. 1958:151–154.

CHAPMAN, H. H. 1952. The place of fire in the ecology of pines. Bartonia 26:39–44.

FOOTE, L. E., AND J. A. JACKOBS. 1966. Response of partridgepea (*Cassia fasciculata* Michx.) and Korean Lespedeza (*Lespedeza stipulacea* L.) to differences in soil types, phosphorus fertilization, and plant populations. Agron. J. 58:419–423.

FORDHAM, A. J. 1965. Germination of woody legume seed with impermeable seedcoats. Arnoldia 25(1):1–8.

GARREN, K. H. 1943. Effects of fire on vegetation of the southeastern United States. Bot. Rev. 9:617–654.

GREEN, S. W. 1935. Effect of annual grass fires on organic matter and other constituents of virgin longleaf pine soils. J. Agr. Res. 50:809–822.

HEYWARD, F. 1938. Soil temperatures during forest fires in the longleaf pine region. J. Forest. 36:478–491.

HOFMANN, J. V. 1925. Laboratory tests on effect of heat on seeds of noble and silver fir, western white pine, and Douglas fir. J. Agr. Res. 31:197–199.

KAWATAKE, M., K. TAKIZAWA, AND M. KATAYAMA. 1955. Studies on the developmental processes of hard seed of some legumes. Dev. Plant Breed. and Cult. Bull. 30:177–182, 193–202 Takai-Kinki.

KOLLER, D., AND M. NEGHI. 1966. Germination of seed of desert plants. Dep. of Bot., Hebrew Univ., Jerusalem, Israel. 180 p.

LITTLE, S., AND E. B. MOORE. 1953. The ecological role of prescribed burns in the pine–oak forests of southern New Jersey. Ecology 30:223–233.

LUTZ, H. J. 1956. Ecological effects of forest fires in the interior of Alaska. U.S. Dep. Agr. Tech. Bull. 1133:121.

MARTIN, R. E., AND C. T. CUSHWA. 1966. Effects of heat and moisture on leguminous seed. 5th Tall Timbers Fire Ecol. Conf. Proc., Tallahassee, Florida.

MAYER, A. M., AND POLJAKOFF-MAYBER. 1963. The germination of seed. The Macmillan Co., New York. 236 p.

ODUM, E. P. 1953. Fundamentals of ecology. W. B. Saunders Company, Philadelphia. 384 p.

RAMPTON, H. H., AND TE MAY CHING. 1966. Longevity and dormancy in seed of several cool-season grasses and legumes buried in soil. Agron. J. 58:220–223.

SAMPSON, A. W. 1952. Range management principles and practices. John Wiley & Sons, Inc., New York. 570 p.

STODDARD, H. L. 1931. The bobwhite quail. Charles Scribner's Sons. 559 p.

STODDARD, H. L. 1961. The cooperative quail study association. Misc. Pub. No. 1. Tall Timbers Res. Sta., Tallahassee, Florida. 500 p.

STONE, E. C., AND G. JUHREN. 1951. The effects of fire on the germination of seed of *Rhus ovata* (Wats.). Amer. J. Bot. 38:368–372.

TOOKEY, H. L., AND Q. JONES. 1965. New sources of water-soluble seed gums. J. Econ. Bot. 19(2):165–174.

UGGLA, E. 1958. Ecological effects of fire on North Swedish Forests. Univ. Uppsala, Inst. of Plant Ecol. 18 p.

WAHLENBERG, W. G. 1935. Effect of fire and grazing on soil properties and the natural reproduction of longleaf pine. J. Forest. 33:331–338.

WEAVER, H. 1959. Effects of burning on range forage values in the ponderosa pine forests. Soc. Amer. Forest. Proc. 1958:212–215.

WENT, F. W., G. JUHREN, AND M. C. JUHREN. 1952. Fire and biotic factors affecting germination. Ecology 33:351–364.

WRIGHT, E. 1931. The effect of high temperatures on seed germination. J. Forest. 29:679–687.