INFLUENCE OF A PRESCRIBED BURN ON COLONIZING BLACK LOCUST

Roger C. Anderson and Lauren E. Brown[1/]

Abstract.--On Sand Prairie Scrub Oak Nature Preserve the Illinois Department of Conservation has used fire to maintain a mosaic of closed forest, savannah, and sand prairie and to control invading black locust. Our three year study of locust response to burning revealed that locust readily resprouts. All stems were fire-killed, but shortly after the burn smaller stems increased substantially. In the sand prairie, locust seedlings increased from 27,062 stems/ha before the burn to 55,937 stems/ha one growing season after the burn. Stems in the sapling category were also resprouts after the burn; however, they decreased from 300 stems/ha before the burn to 50 stems/ha one growing season later. During the next two years, seedlings decreased in number as resprouts grew larger and mortality exceeded resprouting, but the number of saplings increased. In burned forested areas, trees > 9.0 cm dbh experienced heavy mortality. Seedlings and saplings had changes in density similar to those described for the prairie, although there were fewer stems. In a non-burned forest, seedlings decreased from 5,375 to 2,938 stems/ha and saplings increased from 50 to 375 stems/ha during the three year study period.

Additional keywords: Black locust, Robinia pseudoacacia, fire, sand prairie, resprouting, colonize, pest.

Black locust (Robinia pseudoacacia L.) has been widely planted as a windbreak tree, to control soil erosion, as a nectar source for domestic bees, and as a source of durable wood for fence posts. Because it has been so widely introduced it is difficult to assess the species' geographic range and its ecology in undisturbed ecosystems. However, before its widespread introduction by man its distribution was probably limited to the Appalachian Mountains and portions of the Ozark and Ouachita Mountains in Oklahoma, Arkansas, and Missouri (Roach 1958, Keresztesi 1977).

Numerous studies have dealt with this species' physiology and biochemical characteristics (e.g., Höll 1974, Podstolski and Brown 1974, Siminovitch 1975, Brown and Bixby 1976, Yoshida 1979), but relatively little information is available on its ecology. However, species like black locust that are widely planted by man because of their utilitarian value, should receive attention from ecologists because of their potential to become serious pests. Other examples of such plants include Tatarian honeysuckle (Lonicera tatarica L.) and Morrow's honeysuckle (Lonicera morrowi Gray) in southern Wisconsin (Barnes and Cottam 1974), multiflora rose (Rosa multiflora Thunb.) in the Midwest (Klimstra 1956), and kudzu (Pueraria lobata (Willd.) Ohwi.) and Japanese honeysuckle (Lonicera japonica Thunb.) in the southeastern United States (Oosting 1956).

1/ Professor of Plant Ecology and Professor of Vertebrate Zoology, Department of Biological Sciences, Illinois State University, Normal, Illinois 61761. We thank: the Illinois Nature Preserves Commission and Illinois Department of Conservation for permitting this study to be conducted on Sand Prairie Scrub Oak Nature Preserve; and J. Schwegman and R. Schanzle for advice and help.

On the Sand Prairie Scrub Oak Nature Preserve, Mason County, Illinois, controlling the introduced black locust is a serious management problem. The Preserve occurs on deep sand deposits laid down by glacial melt waters in the Illinois River Valley during the Pleistocene (Willman and Frye 1970). Following the last glacial period these sand deposits were worked by wind action into dune systems. In presettlement times they primarily supported a mosaic of: (1) sand prairies dominated by sandlove grass (Eragrostis trichoides (Nutt.) Wood), little bluestem (Schizachyrium scoparium (Michx.) Nash), sandreed grass (Calamovilfa longifolia (Hook.) Scribn.) and other species; (2) closed oak-hickory forests (black oak--Quercus velutina Lam., blackjack oak--Q. marilandica Muennchh., mockernut hickory--Carya tomentosa (Poir.) Nutt., black hickory--C. texana Buckl.); and (3) savannahs where blackjack oak was the dominant tree species (Rodgers and Anderson 1979). Many sand prairie areas were cultivated or grazed during the first part of this century and the forests were subjected to grazing and periodic burning.

Removal of sand prairie vegetation during cultivation, especially on dunes, encouraged wind erosion and many dunes became active. In the decade 1930-40, black locust and other tree species (e.g., Pinus banksiana, Lamb., P. strobus L., P. rigida Mill.) were introduced to control wind erosion. In this same time period, Sand Ridge State Forest was established to demonstrate that a forestry industry could be supported by trees grown on these sandy, poor quality soils. However, in recent years the availability of commercial fertilizer and abundance of ground water for irrigation enhanced the agricultural value of sandy soils in the area.

The 590 ha Sand Prairie Scrub Oak Nature Preserve was established in 1970. Much of this land was probably subjected to at least some prior agricultural use. However, invasion by agricultural weeds is limited and if left alone many of the former agricultural fields may undergo succession to sand prairie (Curtis 1959).

By the time the preserve was established, black locust had invaded large areas of sand prairie (several ha) and some adjacent forest. Aerial photographs taken in 1938 show sizable locust patches (J. Schwegman, pers. com.). Previous workers reported that fire curbs invasion of woody species into prairie sites in the Midwest (Curtis 1959, Vogl 1974, Anderson and Van Valkenburg 1977). Fire was chosen as a management tool for the preserve because of the desire to convert the oak-hickory forests to a mosaic of closed forest and savannah, and to control woody plant invasion into the sand prairie. This paper reports on a three year study of the response of black locust to a prescribed burn.

METHODS

We sampled in three areas: (1) a sand prairie; (2) a blackjack oak-black hickory forest adjacent to the sand prairie; and (3) a black oak-black hickory forest located about 200 m from the two former areas.

In the sand prairie four permanent sampling points were established to serve as the center of three nested circular quadrats. At each point all tree stems > 20 cm tall were sampled in three size classes. Stems > 20 cm tall but $\leq$ 1.0 cm dbh were considered to be seedlings, saplings were stems > 1.0 cm dbh but $\leq$ 9.0 cm dbh, and trees were stems > 9.0 cm dbh. Seedlings, saplings, and trees were sampled in quadrats .004, .01, and .04 ha, respectively.

Three permanent points were also located in the adjacent blackjack oak-black hickory forest that was being invaded by locust. In the forest we were initially interested in studying tree mortality and only stems > 9.0 cm were sampled prior to the burn. The first sampling of the blackjack oak-black hickory forest and prairie was carried out in December 1976 and January and February 1977. Prairie and forest sites were subjected to prescribed burning on 16 March 1977. During the next three years, because of rapid invasion of locust into the burned forest, all woody stems > 20 cm tall were sampled near the end of the growing season (August-September).

In the black oak-black hickory forest, five permanent sampling points were established in September of 1977 to sample trees (stems > 9.0 cm dbh) and at four of these points seedlings and saplings were also sampled. This area had a few black locust trees, and locust seedlings and saplings had become established. This forest had trees with a maximum age of 80-85 years and occupied a slight depression on the backside of a broad dune.

The black oak-black hickory forest was not burned on 16 March 1977, but this area and the two other study areas were burned earlier on 26 March 1974. The earlier burn did not appear to have had much effect on the black oak-black hickory forest, but the effect was more noticeable in the other two study areas. This was particularly true in the blackjack oak-black hickory forest where some trees were killed.

Seedling and sapling densities (stems/ha) were computed for the three study areas by species for each size class by year. Contingency Chi-square was used to test for shifts in distribution of locust stems by size class between consecutive years. For the burned and unburned forest areas, tree density (stems/ha), basal area (m^2/ha), and Importance Values (based on the sum of relative dominance and relative density divided by two) were calculated. Contingency Chi-square was also used to test for changes in distribution of tree stems among species between sampling years. For Chi-square analyses the number of stems sampled was used and not the calculated stems/ha.

RESULTS

The prescribed burn occurred on 16 March 1977 between 12:40 and 2:45 PM. During the burn air temperature varied from 16.6-17.8 C, relative humidity ranged from 26-28%, and the wind out of the W-NW averaged 3.2 m/second with gusts up to 4.0 m/second. The fire carried well across sand prairie and into the forest with flames often in excess of 5 m in height.

There was complete mortality of all aboveground locust stems in the burned areas. However, following the burn there was a significant ($p < .001$) increase in number of black locust seedlings in the prairie resulting from resprouting (the number of stems more than doubled--Table 1). Saplings were reduced to about 83% of their preburn density; this change was also significant ($p < .01$). Again, as in the seedling class, all sapling stems were resprouts. In the second and third years following the fire, black locust seedlings in the prairie decreased and became less abundant in 1979 than they were prior to burning. Differences in seedling density between the preburn sample and the 1978 and 1979 samples were significantly different ($p < .001$ and $p < .05$, respectively). In contrast, black locust saplings were significantly

more numerous in the second year ($p < .001$) and third year ($p < .001$) following burning than they were prior to the prescribed burn (Table 1). A similar response is suggested by the locust data for the blackjack oak-black hickory forest (Table 1), although information is not available for preburn conditions. The shift in stems from the seedling to the sapling class during the three years following the burn may be interpreted as a wave of initial reproduction, growth of these stems into the sapling class, and a subsequent reduction in resprouting (perhaps through competition or apical dominance).

Table 1.--Changes in stem density (stems/ha) for seedlings (SD) and saplings (SP) before and after the prescribed burn

Sample date	Prairie		Burned forest		Unburned forest	
	Black locust					
	SD	SP	SD	SP	SD	SP
1976-1977 (preburn)	27,062	300	---	---	---	---
1977	55,937	50	11,117	67	5,375	50
1978	35,376	1,000	8,083	533	4,000	100
1979	23,250	2,175	8,500	600	2,938	375

In the unburned black oak-black hickory forest, seedling stem density significantly decreased ($p < .001$) from 1977 to 1979 and sapling density significantly increased ($p < .005$) suggesting a pattern similar to that observed on the burned sites between 1977 and 1979. However, in the unburned forest there were many fewer locust seedlings and saplings than in the prairie or burned forest.

The burned blackjack oak-black hickory forest experienced heavy mortality among trees during the three years following the burn of 16 March 1977. The greatest mortality occurred during the first year when 34.1% of the trees died. In the second and third years following the burn 4.9% and 8.5% died, respectively. A significant change in tree density (Table 2) occurred between 1976-1977 (preburn) and the end of the 1979 growing season ($p > .001$). There was also a decrease in the Importance Value of blackjack oak, whereas black hickory increased in importance during the same time period (Table 3). The Importance Values of black oak remained relatively constant during the study period. These results suggest that black hickory may be less susceptible to fire than blackjack oak in a forest environment. Because Importance Values are percentage values, changes in IV's were not tested statistically. However, Bartlett's Test (Bailey 1959) was used to test for a homogenous distribution of the total tree stems among the three species between 1976-77 and 1979. No significant differences were found ($p > .25$).

Table 2.--Tree (stems > 9.0 cm dbh) density and basal area in the burned and unburned forests for all species

	Burned forest				Unburned forest		
	Preburn	1977	1978	1979	1977	1978	1979
Stems/ha	638	450	417	358	335	305	315
m^2/ha	19.1	15.3	15.0	13.7	25.0	22.3	21.4

Table 3.--Changes in Importance Values for tree species in the burned and unburned forests

Species	Burned forest				Unburned forest		
	Preburn	1977	1978	1979	1977	1978	1979
Quercus velutina	3.7	2.3	2.5	3.5	82.4	79.8	77.8
Carya texana	31.8	41.1	41.2	41.3	9.8	11.6	12.3
Q. marilandica	64.5	56.6	56.3	55.2	4.9	3.8	3.9
Robinia pseudoacacia	0.0	0.0	0.0	0.0	2.9	4.7	5.9

In the black oak-black hickory forest there was also no significant change in tree stem density (Table 2) between 1977 and 1979 ($p < .50$). Black oak and blackjack oak decreased in Importance Value, whereas black hickory and black locust showed slight increases in Importance Value (Table 3). Again, changes in IV's were not tested statistically.

DISCUSSION

Our results indicate that black locust is not controlled by fire and its spread is encouraged by burning. In contrast Anderson and Van Valkenburg (1977) found that fire reduced the abundance of several woody species invading prairie vegetation. These included red maple (Acer rubrum L.), American hazelnut (Corylus americana Wait.), eastern red cedar (Juniperus virginiana L.), aromatic sumac (Rhus aromatica Ait.), multiflora rose, and blackberry (Rubus pensylvanicus Poir.). Anderson and Schwegman (1971) reported that fire reduced the abundance of Japanese honeysuckle, but resprouting was vigorous by prairie willow (Salix humilus Marsh.), silky dogwood (Cornus ammomum), and black walnut (Juglans nigra L.). The prairie willow showed a strong tendency to spread.

Although our study has found black locust to invade burned forests, it is extremely shade intolerant (Roach 1958). The spread of black locust into undisturbed forest communities normally occurs quite slowly, if at all. However, none of the dominant tree species in the Sand Prairie Scrub Oak Nature Preserve are shade tolerant. Thus, if openings occur in the forest, black locust has a chance to become established. In our study fire reduced competition in the forest by killing canopy trees and enhanced the spread of black locust.

Occasional fires are normally effective in maintaining prairies. However, it is apparent that parts of the Preserve will be rapidly converted to black locust thickets if fire is the only management tool used. Black locust in areas not subjected to burning will at least maintain itself and probably spread into undisturbed sand prairie.

LITERATURE CITED

Anderson, R., and J. Schwegman. 1971. The response of southern Illinois barren vegetation to prescribed burning. Trans. Ill. State Acad. Sci. 64: 287-291.

Anderson, R. C., and C. Van Valkenburg. 1977. Response of a southern Illinois grassland community to burning. Trans. Ill. Acad. Sci. 69:399-414.

Bailey, N. 1959. Statistical methods in biology. 200 p. London: The English Univ. Press Ltd.

Barnes, W. J., and G. Cottam. 1974. Some autoecological studies of the Lonicera x bella complex. Ecology 55:40-50.

Brown, G. N., and J. A. Bixby. 1976. Relationship between black locust seedling age and induction of cold hardiness. For. Sci. 22:208-210.

Curtis, J. 1959. The vegetation of Wisconsin. 657 p. Madison: Univ. Wisconsin Press.

Höll, W. 1974. Dark CO_2 fixation by cell-free preparations of the wood of Robinia pseudoacacia. Can. J. Bot. 52:727-734.

Keresztesi, B. 1977. Robinia pseudoacacia; The basis of commercial honey production in Hungary. Bee World 58:144-150.

Klimstra, W. D. 1956. Problems in the use of multiflora rose. Trans. Ill. State Acad. Sci. 48:66-72.

Oosting, H. J. 1956. The study of plant communities. 440 p. San Francisco: W. H. Freeman and Co.

Podstolski, A. J., and G. N. Brown. 1974. L-phenylalanine ammonia-lyase activity in Robinia pseudoacacia seedlings, I. Cyclic phenomenon activity during continuous light. Plant Physiol. 54:41-43.

Roach, B. J. 1958. Silvical characteristics of black locust. USDA Forest Serv. Misc. Release 30, 15 p. Columbus, Ohio.

Rodgers, C. S., and R. C. Anderson. 1979. Presettlement vegetation of two Prairie Peninsula counties. Bot. Gaz. 140:232-240.

Siminovitch, D. 1975. Protoplasts surviving freezing to -196 C and osmotic dehydration in 5 molar salt solutions prepared from the bark of winter black locust trees. Plant Physiol. 63:722-725.

Vogl, R. 1974. Effect of fire on grasslands. In T. T. Kozlowski and C. E. Ahlgren (eds.) Fire and ecosystems, p. 139-194. N. Y.: Academic Press.

Willman, H. B., and J. C. Frye. 1970. Pleistocene stratography of Illinois. Ill. State Geol. Sur. Bull. 94, 204 p. Urbana, Ill.

Yoshida, S. 1979. Freezing injury and phospholipid degradation in vivo in woody plant cells I. Subcellular localization of phospholipase D in living bark tissue of the black locust tree (Robinia pseudoacacia L.). Plant Physiol. 64:241-246.