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PLAINS COTTONWOOD REGENERATES FROM NATURAL SEEDFALL ON DISTURBED, IRRIGATED SITES

In relatively arid regions of interior western North America, riparian forests are generally dominated by cottonwood (*Populus*). Cottonwood forests provide important habitat for mammals and birds, especially where uplands are too dry to support trees. Riparian forests are failing to regenerate downstream of many dams from as far north as Alberta to as far south as Arizona.

Cottonwood seedlings are sensitive to drought and intolerant of shade; therefore, they are usually found on moist, recently deposited sediment. Construction of dams and regulation of water flows typically decrease downstream peak flows and sediment load. Where dams have been constructed along meandering streams, the lateral migration of channels has sbeen greatly reduced. Reduction of lateral migration of channels has reduced the rate of formation of bare, moist sites available for seedling establishment of cottonwood. We hypothesized that if reproduction is limited by a shortage of bare, moist sites, we could restore stands of cottonwood by using natural seedfall in artificially disturbed, irrigated locations. We used an experimental approach to test this hypothesis along Boulder Creek, a dammed, formerly meandering stream on the plains of Colorado. We focused on plains cottonwood (*Populus deltoides* subsp. *monilifera*), the dominant native tree in bottomlands of the Colorado plains and an important component of riparian forests throughout the Great Plains.

CONTROLLED EXPERIMENT DISTINGUISHES THE EFFECTS OF IRRIGATION, DISTURBANCE, AND SEED ABUNDANCE

The Boulder Creek bottomland is dominated by grasses and herbs with widely scattered cottonwoods. In our 1-km study reach there were six old, female cottonwood trees. The only younger individuals were restricted to two channel islands. We carried out a three-way factorial experiment with two levels for each treatment. The three pairs of contrasting treatments were daily sprinkler irrigation versus no irrigation, removal of the top 16.5 cm of sod versus no sod removal, and natural seedfall plus added seed versus natural seedfall alone. Each of the eight treatment combinations occupied a plot 2 m wide extending from the water's edge to the terrace. The design was replicated in three blocks along the study reach. Cottonwood seeds are released in late spring and remain viable for only a few weeks. Therefore, use of naturally dispersed seeds requires synchronization with the period of peak seed release; in 1992, this period was the first 2 weeks of June. Between 15 and 25 September 1992 we counted all woody seedlings in all 24 plots. We made a second count on 16 September 1993.

IRRIGATION AND DISTURBANCE ARE NECESSARY FOR ESTABLISHMENT

The creation of bare, moist surfaces greatly increased seedling establishment, and sufficient viable seeds were

delivered by natural seedfall to colonize the created sites (Table). In unirrigated, undisturbed plots, mean cottonwood density was 0.03 seedlings/m^2. Irrigation or disturbance alone produced mean cottonwood densities of 0.39 and 0.75 seedlings/m^2 (Table). Plots that were both irrigated and disturbed produced a mean cottonwood density of 10.3 seedlings/m^2. The effects of irrigation and disturbance on cottonwood establishment were significant ($P < 0.005$); adding seed to supplement natural seedfall had no significant effect ($P = 0.78$). The few cottonwood seedlings in unirrigated plots with intact sod were in low positions susceptible to scour by future moderate flows.

The overall density of cottonwoods in the irrigated plots in September 1993—after a year without irrigation—was 21% of the density in September 1992. Most of the surviving cottonwoods had grown more than 100% in height in 1993 and showed no sign of drought stress. Therefore, one season of irrigation was sufficient to produce cottonwoods large enough to survive an additional year without supplemental irrigation.

Not all species in the willow family (Salicaceae) respond as well as cottonwood to sprinkler irrigation. In a similar experiment, establishment of peachleaf willow (*Salix amygdaloides*) was not increased by daily sprinkler irrigation, apparently because seedlings could not survive dry surface conditions between waterings.

Restoration of Cottonwood Forest Can Be Accomplished by Using Natural Seedfall

Watershed development often leads to dam construction to reduce peak flow, and bank stabilization to prevent channel migration and decrease sediment load. However, floods, sediment deposition, and channel change are essential for establishment of pioneer species like plains cottonwood. Where flow regulation and channel stabilization have eliminated the formation of seedling establishment sites, active management is probably necessary to maintain a cottonwood population. When there is no nearby source of cuttings, use of natural seedfall can allow regeneration of the local population without altering the gene pool. Because saltcedar (*Tamarix spp.*) also produces windblown seeds capable of growing on wet mineral soil, this exotic will probably become established with cottonwood on disturbed irrigated sites if seedbearing individuals are nearby.

The techniques described here could be modified to increase seedling yield and decrease costs. To minimize competition from tall, deep-rooted herbs, a site with a grass cover, sandy sediment, and low organic matter content should be chosen. These are characteristics of the most successful block in our experiment—Block 1 (Table). Establishment sites should be high enough to avoid annual scour by water or ice. Plots as large as those in our experiment are appropriate for producing a plantation as a source of local material for cuttings; however, if the seedlings are to be grown to adulthood on site, large plots are inefficient because intraspecific competition will eventually kill almost all individuals. For establishment of a stand of adults, it would be better to dig many small, widely spaced shallow depressions 2 m in diameter, 30 cm deep in the center, and sloping gradually up to ground level at the edges. Cottonwood seedlings are intolerant of shade, and are unlikely to thrive in partly shaded clearings beneath existing trees.

In many riparian areas, an upstream dam and reservoir allow prescription of moderately high flows to moisten surfaces at a designated time, but residential and industrial development prevent the use of higher flows powerful enough to form new bare surfaces. In this situation, cottonwood forest may be established by artificially disturbing a riparian site with a backhoe or bulldozer, flooding the area before seed dispersal, and then preventing high flows destructive to young trees during the next few years. Establishment of cottonwood forest is often desired as part of the restoration of a former gravel mine or a construction site. Our experiment suggests that cottonwoods can be established at low cost in such sites by creating a very gradual slope and manipulating water levels so that high water coincides with the beginning of cottonwood seed release.

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Table. Density of plains cottonwood in plots at the end of the first growing season, 15-25 September 1992.

	Unirrigated		Irrigated	
Sod sediment	Unseeded	Seeded	Unseeded	Seeded
Sod intact				
Block 1	0.00	0.00	1.41	0.12
Block 2	0.00	0.00	0.02	0.00
Block 3	0.08	0.07	0.37	0.40
Sod Removed				
Block 1	0.00	0.00	15.67	35.60
Block 2	1.02	1.71	1.44	2.93
Block 3	1.58	0.21	2.10	4.27