Establishment of Rio Grande Cottonwood Seedlings Using Micro-irrigation of Xeric Flood Plain Sites

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Abstract—Flood control, irrigation structures, and flow control practices on the Middle Rio Grande have prevented the deposition of sediments and hydrologic conditions conducive to the germination and establishment of Rio Grande cottonwood (*Populus fremontii* S. Wats.). The Los Lunas Plant Materials Center has been investigating the use of micro-irrigation systems on xeric flood plain sites to promote regeneration from natural cottonwood seed dispersal. The initial study showed no establishment benefits resulting from organic–rich substrates versus indigenous mineral surface soil. In the second study, three emitter types (53 L/hr spitter, 14 L/hr spitter, 24 L/hr bubbler) produced mean wetted soil surface areas of 2.7, 0.58, and 0.33 m^2, respectively, and median seedling counts per plot of 70, 29, and 16, respectively. In the initial study, the plots with the greatest cottonwood seedling density after one growing season contained 22 seedlings/m^2 (15 cm height) without weed control (infested with *Kochia scoparia* (L.) Roth) and 86 seedlings/m^2 (69 cm height) with weed control. Primary weed pests in the second study were *Tamarix*, *Cenchrus*, and *Artemisia* species; weed infested plots had 35 to 45 percent fewer seedlings than plots with weed control after one growing season. Technology development will concentrate on reducing labor costs for irrigation operation and weed control, the major costs in applying this technology. Micro-irrigation technology offers an alternative method of managed cottonwood regeneration for sites where flood irrigation or pole plantings are not practical because of economic, engineering, water use, or jurisdictional constraints.

Flood control and irrigation structures as well as flow control practices on the Middle Rio Grande have drastically altered sediment deposition and soil moisture conditions on the flood plain. These changes have prevented the necessary soil conditions and water regimes required for the regeneration of Rio Grande cottonwood (*Populus fremontii* S. Wats.) and other riparian trees and shrubs on flood plain sites remote from the river channel (Whitney 1996). The lack of regeneration of the dominant native trees, the spread of exotic woody species (*Tamarix* spp. and *Elaeagnus angustifolia* L.), and the perturbation in ecosystem function attributable to the lack of flooding has resulted in a rapid decline in the health of the riparian cottonwood forest (Dick-Peddie 1993, Crawford and others 1996).

The Los Lunas Plant Materials Center (USDA-NRCS) has been investigating techniques to reestablish the dominant native trees and shrubs in these degraded riparian cottonwood forests for the past 15 years. These efforts have been made in cooperation with federal (Army Corps of Engineers, Bureau of Reclamation, Bureau of Land Management, Fish and Wildlife Service, Bureau of Indian Affairs), state (Park and Recreation Division, Game and Fish Department) and local agencies (Albuquerque Open Space Division). Throughout the 1980's and early 1990's, these efforts focused on enhancing the success of pole plantings of Rio Grande cottonwood, Goodding's willow (*Salix gooddingii* Ball), and coyote willow (*Salix exigua* Nutt.). Recent studies have investigated the use of pole plantings to establish important shrub species of the cottonwood riparian forest including false indigo (*Amorpha fruticosa* L.), New Mexico olive (*Forestiera neomexicana* Gray), and seepwillow (*Baccharis* spp.). In the past several years, we have redirected much of our research into investigating methods to establish Rio Grande cottonwood seedlings by supplementing surface soil moisture using micro-irrigation techniques.

The existing riparian cottonwood forest disseminates massive quantities of viable seed within the flood plain of the Rio Grande. Soil moisture conditions conducive to the germination and early survival of these seedlings are generally only found on banks and sandbars. Most of these seedlings are washed away by high water flows the following spring (Whitney 1996). We investigated the concept of providing a precise application of water to xeric flood plain sites remote from the river channel to create an optimum seedbed for seed adherence, germination, and seedling survival until the sapling roots reach the capillary fringe above the water table. If this technique proves feasible, it may substantially reduce the costs of forest regeneration in relation to pole planting, which typically costs from 25 to 40 dollars per pole (Los Lunas Plant Materials Center 1997). Costs of pole plantings include not only the immediate expense of dormant pole cuttings and installation, but also the costs involved with pest damage control (for example, tree guard installation and cottonwood leaf beetle suppression). However, seedlings established using micro-irrigation will also require cottonwood leaf beetle control. In addition to the potential economic incentives, the use of micro-irrigation to

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establish a cottonwood riparian forest from natural seed dispersal will impart much greater genetic diversity than is achieved by planting poles derived from clones in production nurseries.

This paper addresses our initial proof of concept studies which sought to determine: 1) the effect of organic-rich substrates on seedling survival and growth; 2) the influence of different types of micro-irrigation emitters on the area of wetted soil surface and the number of seedlings established; 3) the effect of weed competition on seedling density and height growth; 4) the amount of irrigation water applied during the germination and early establishment phase; and, 5) irrigation system design and costs of a hypothetical large scale cottonwood regeneration project. Discussion of future investigations concentrate on 1) reducing costs for irrigation operation and weed control, 2) simplifying the micro-irrigation system, and 3) minimizing water use.

1996 Study—Soil Surface Treatments

Observations of volunteer cottonwood seedlings in the bare-root nursery at the Plant Materials Center indicated seedling establishment occurred on organic-rich soil-less mixes with micro-sprinkler irrigation every 6 hours. These observations prompted trials of surface materials that might promote seedling establishment by increasing cottonwood seed adherence and providing optimum moisture during germination and early growth. The cost of soil-less mix compelled the testing of less expensive organic substrates and 2 different thickness' of these surface treatments.

Methodology

The study was conducted at the Rio Grande Nature Center on disturbed sandy loam soils having a severe infestation of summer cypress (*Kochia scoparia* (L.) Roth). Plots (each 2.4 m x 3.0 m) were dug to a depth of 0.15 m with the bucket of a front end loader tractor. The plots were ripped an additional 0.5 m in depth to break a caliche layer. The plots were then back-filled with indigenous mineral soil, mulch, or soil-less mix to provide 2 depths of organic substrates. The surface treatments were as follows: 1) indigenous soil, 2) shredded residential green waste 5 cm thick, 3) shredded residential green waste 15 cm thick, 4) soil-less mix (component volume ratio 6:3:1 pumice:peat:composted bark) 5 cm thick, and 5) soil-less mix 15 cm thick. The plots were replicated in 3 blocks with the treatments in random order. Regardless of the thickness of the soil treatment, the surface of plots was level with the surrounding terrain so surface runoff would not flow onto the plots.

Each of the 15 plots was irrigated with one variable flow micro-sprinkler having a maximum flow rate of 87 L/hr, a 90 degree spray pattern, and a wetted plot area of 5m^2. The 15 micro-sprinklers were connected to lateral surface pipelines of 0.75 inch polyethylene tubing with 0.25 inch micro-tubing. Irrigation frequency and duration were controlled using a battery operated irrigation controller. The water source was an existing shallow well with a photo-voltaic powered submersible pump.

Irrigation of the plots was started on May 3, 1996 to allow germination of weed seed. A 2 percent solution of glyphosate ('Roundup') was applied twice to reduce weed populations prior to cottonwood seed dissemination. At this location, seed dispersal began May 31, 1996 and continued until July 20, 1996. For 5 weeks, 23 L of water were applied 4 times daily at 3 hr intervals to each plot (i.e., 92 L/day per plot or 3.1 gal/week per square foot). On July 9, 1996, the irrigation schedule was changed to a weekly application of 870 L per plot in a single ten hour period (i.e., 4.3 gal/week per square foot) until November 1, 1996 when irrigation was stopped. In April 1997, irrigation resumed with 1500 L per plot applied once a month in a single 3 day period (i.e., 1.7 gal/week per square foot).

On July 2, 1996, hand weeding of one experimental block of 5 treatments was stopped to examine the effect of weed competition on cottonwood establishment; these plots are denoted as NWC (no weed control). The other plots, WS (weed suppression), were hand weeded weekly for the remainder of the 1996 growing season. A pre-emergent herbicide (0.17 percent pendimethalin, 'Stomp') was applied to the WS plots in March 1997 after spot spraying volunteer grass seedlings with a 2 percent glyphosate solution. In addition, the WS plots were hand weeded in July and August 1997. In 1997, the seedlings were sprayed with a 0.001 percent solution of cyfluthrin ('Tempo II') monthly from June to October to control cottonwood leaf beetle. Cottonwood seedling density was measured in November 1996 and 1997 using a meter square frame placed in the center of each plot; seedling height of 5 to 10 seedlings per plot was also recorded.

Results and Discussion

By July 1, 1996, the larger seedlings in the indigenous soil treatment were in the four to five leaf stage (5 to 8 cm in height) and had root lengths of up to 10 cm. In contrast, the seedlings in the shredded green waste and soil-less mix treatments were stunted with heights of 2 to 3 cm, root lengths less than 8 cm, and red to yellow discoloration. On July 2, each WS plot was fertilized by applying 50 L of 100 mg/L nitrogen (10 kg/ha) as a soluble fertilizer solution ('Peters 20-10-20 Peat Lite Special' with minor- and micronutrients). The NWC plots were not fertilized.

After the first growing season, the WS treatments having the greatest seedling density and tallest seedlings were the indigenous soil (77 seedlings/m^2 and 0.75 m) and the shredded green waste 5 cm thick (86 seedlings/m^2 and 0.69 m) as shown in table 1. After the second growing season, these same treatments had the tallest seedlings; the seedling density of the indigenous soil treatment (25 seedlings/m^2) was not significantly different than the other treatments except for the 15 cm thick soil-less mix (11 seedlings/m^2). These data show no benefit in seedling growth or establishment as a result of the organic-rich surface treatments. The micro-irrigation schedule apparently provided equivalent seed adherence and surface moisture for the establishment of cottonwood seedlings on indigenous mineral soil negating any perceived benefits of the organic-rich substrates.

The seedling density after the second growing season ranged from 24 to 33 percent of the density after the first

Table 1—Rio Grande cottonwood seedling height and seedling density on micro-irrigated plots at the Rio Grande Nature Center. Means and standard errors reported for plots with weed suppression and fertilizer application; plots with no weed control or fertilizer application were not replicated.

	Surface treatments				
	Indigenous soil	**Soil-less mix 5 cm**	**Soil-less mix 15 cm**	**Green waste 5 cm**	**Green waste 15 cm**
Plots with weed suppression and fertilizer application					
Mean seedling height (m)					
After first growing season	0.75	0.39 c	0.23 c	0.69	0.47 b
(Standard error)	(0.01)	(0.02)	(0.03)	(0.08)	(0.04)
After second growing season	1.75	1.28	0.77 b	1.61	1.35 b
(Standard error)	(0.10)	(0.24)	(0.14)	(0.22)	(0.05)
Mean seedling density (no./m^2)					
After first growing season	77	63 c	15 c	86 a	57 b
(Standard error)	(2)	(1)	(5)	(4)	(4)
After second growing season	25	21	11 b	21	19
(Standard error)	(2)	(2)	(2)	(3)	(8)
Plots with no weed control and no fertilizer application					
Seedling height (m)					
After first growing season	0	0	0	0.15	0.15
After second growing season	0	0	0	0.51	0
Seedling density (no./m^2)					
After first growing season	0	0	0	22	4
After second growing season	0	0	0	7	0

a Mean significantly different from indigenous soil treatment at $P \leq 0.10$ and $P > 0.05$.
b Mean significantly different from indigenous soil treatment at $P \leq 0.05$ and $P > 0.01$.
c Mean significantly different from indigenous soil treatment at $P \leq 0.01$.

growing season for treatments with high initial densities. The competition for light, nutrients, and water resulted in a substantial natural thinning process.

Those plots with no weed control or fertilizer additions showed very little if any survival after the first growing season. Only the shredded green waste plots showed negligible survival and growth after the first growing season. The coarse texture of the shredded material might have reduced weed establishment allowing some cottonwood seedlings to survive.

This initial experiment clearly showed that indigenous mineral soils could provide a satisfactory substrate for cottonwood seedling establishment if surface soil moisture is precisely controlled. At this site, weed competition and low fertility favored weeds over cottonwoods even with non-limiting soil moisture.

1997 Study—Evaluation of Micro-irrigation Devices

The 1996 study showed that micro-sprinklers could provide sufficient control of surface moisture to allow cottonwood seedling establishment. The large wetted area produced by these sprinklers resulted in a large dense thicket of seedlings. Smaller wetted areas would require less natural thinning by competition, reduce weed control efforts, and reduce the amount of water to establish cottonwoods on one spot (with the eventual thinning to one tree). Therefore, the goal of the 1997 study was to determine the number of seedlings established in wetted areas created by 3 micro-irrigation emitter types. In addition, the 1997 study site was more representative of typical restoration locales which lack existing wells and pumping equipment and comprise large disturbed areas.

Methodology

The 0.4 ha site is located just downstream of the confluence of the Calabacillas Arroyo on the west bank of the Rio Grande within the Rio Grande State Park (administered by the Albuquerque Open Space Division). Approximately three-fourths of site was enclosed with snow fence to limit disturbance by public activity. The remaining 0.1 ha was not fenced and was adjacent to a horse and walking path. The site characteristics include loamy sand soil and limited vegetative cover primarily of *Artemisia* spp. and *Cenchrus longispinus* (Hack) Fern. (sandbur) with little woody vegetation except a few widely separated coyote willow thickets outside the study site.

A 5 m deep well was developed using a 2 inch well-point. A gasoline-powered centrifugal pump capable of providing 245 L/min at 40 psi and with a suction lift of 4.6 m supplied water to the irrigation system. The discharge was filtered (spin-clean filter) and supplied a 1.5 inch PVC header that spanned the length of the enclosure and extended into the unfenced area. The lateral lines (16 within the enclosure and 2 outside) consisted of 30 psi fixed pressure regulators connected to 0.75 inch polyethylene tubing with capped ends to allow flushing. The emitters were attached to the laterals with 0.125 inch micro-tubing. The 3 emitter types were mini-flow spitters [Roberts Spot-Spitters,] (14 L/hr at 15 psi with a 90 degree spray pattern), medium-flow spitters (53 L/hr at 15 psi with a 160 degree pattern), and a lead-weighted bubbler (24 L/hr at 15 psi with a point source). Each lateral line had between 7 and 10 mini-flow spitters, 4 to 8 medium-flow spitters, and 2 to 3 bubblers for a total of 313 emitters (167 mini-flow, 95 medium-flow, and 51 bubblers). The percentage of water applied by each emitter type was calculated by multiplying the number of emitters by the flow rate; these percentages are 27 percent for mini-flow spitters, 59 percent for medium-flow spitters, and 14 percent for bubblers.

Before initiating the cottonwood establishment study, the study area was irrigated and sprayed biweekly with a 4 percent solution of glyphosate herbicide. Daily irrigation for cottonwood seed germination began June 16, 1997; for the next six weeks the irrigation system was operated during daylight hours at three hour intervals for a period of one half hour. After six weeks, the seedlings were irrigated for three hours once or twice a week depending on precipitation. During seed adherence and germination phase (i.e., first six weeks), from 115 to 190 m^3 of water were applied each week (see fig. 1). In the establishment phase (next 12 weeks), from 10 to 45 m^3 of water were applied each week. For the entire growing season, 1234 m^3 (326,000 gal or 1 acre foot) of water were used in the study during a total application period of 145 hr.

All plots inside the fenced area were hand weeded by the irrigation system operator. On three occasions during the growing season, 8 days of labor were spent weeding the plots inside the enclosure. The plots outside the fence were not weeded during the first growing season. Seedlings were sprayed monthly from August to October 1997 with 0.001 percent cyfluthrin ("Tempo II") to control cottonwood leaf beetle. The numbers of seedlings established in the 313 plots were counted in October 1997. For the medium-flow spitter plots, counts of greater than 100 per plot were recorded and analyzed as a count of 100.

Results and Discussion

At this location, cottonwood seed dispersal began the third week of June 1997. Initial seedling emergence was observed during the fourth week of June. After the first growing season, the mean seedling numbers per plot (± standard error) for each emitter type were as follows: mini-flow spitters 32 (±19) seedlings per plot, medium-flow spitters 67 (± 27) seedlings per plot, and bubblers 20 (±14) seedlings per plot (see table 2). The distribution of seedling numbers for the 3 emitters is presented in figure 2. The most common seedling count classes were 11 to 40 for the mini-flow spitters, 61 to 80 and >100 for the medium flow spitters, and 1 to 30 for the bubblers. Only two out of 313 plots lacked established seedlings in October 1997. The total seedling establishment within the study site after the first growing season exceeded 12,700.

The percentage reduction in seedling density resulting from no weed control was derived from mean seedling counts per plot (and median seedling counts per plot): 37 percent (44 percent), 38 percent (35 percent), and 42 percent (45 percent) for mini-flow spitters, medium-flow spitters, and bubblers,

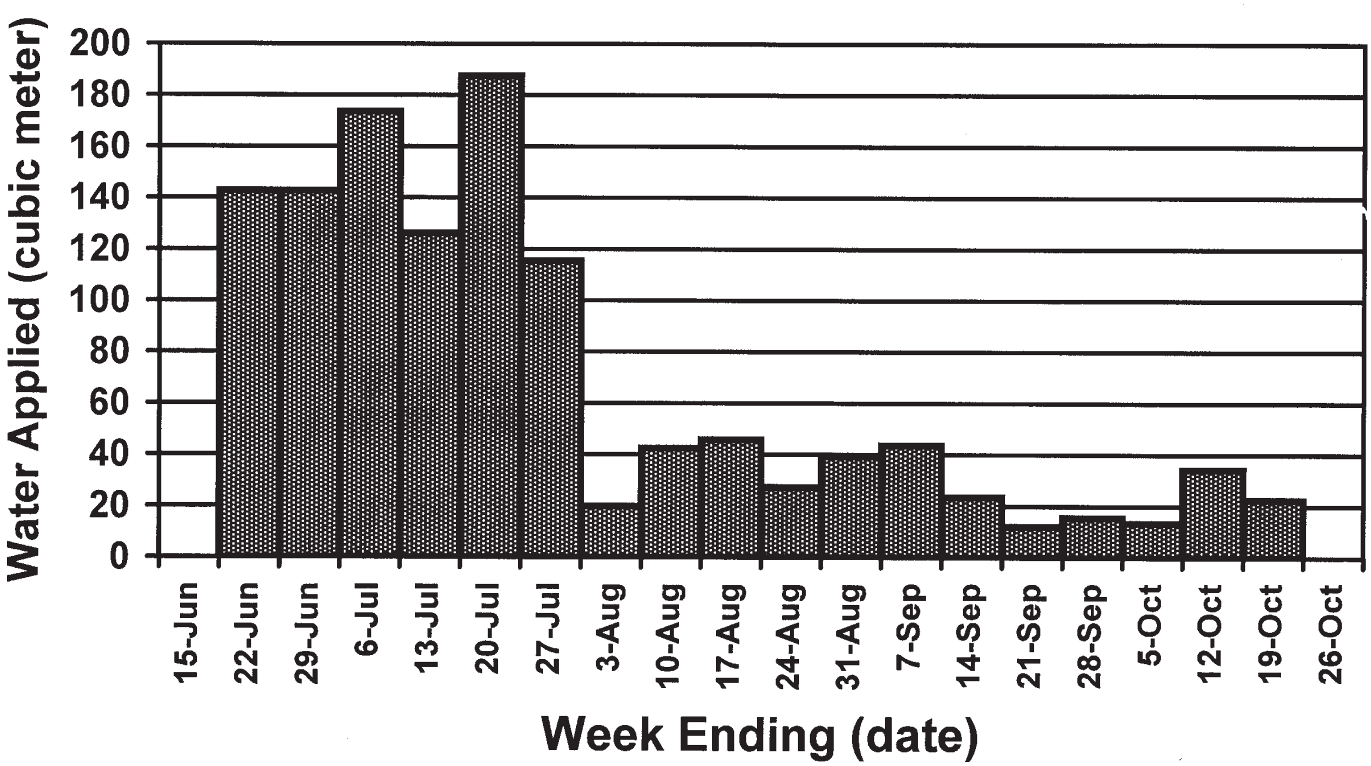

Figure 1—Irrigation water applied during the first growing season to the cottonwood seedling plots at the study site located on the west side of the Rio Grande below Calabacillas Arroyo. Water applied for the week preceding the date given.

Table 2—Number of Rio Grande cottonwood seedlings established per plot during the first growing season using 3 types of micro-irrigation emitters. Study site located on the west side of the Rio Grande below Calabacillas Arroyo.

Emitter type	Plot type a	Number of plots	Median	Mean	Standard error	Most common b	Seedling density c
		(no.)	*(no./plot)*	*(no./plot)*	*(no./plot)*	*(no./plot)*	*(no./m^2)*
Mini-	All	167	29	31.7	19.1	11 to 40	50
flow	WS	148	32	33.1	19.4	nd	55
spitter	NWC	19	18	20.8	12.2	nd	39
Medium-	All	95	70	67.2 d	27.1 d	61 to 80, >100	26
flow	WS	86	72	69.7 d	26.4 d	nd	27
spitter	NWC	9	47	43.2	20.4	nd	17
Bubbler	All	51	16	19.9	14.0	1 to 30	48
	WS	46	18	20.8	14.4	nd	55
	NWC	5	10	12.0	5.5	nd	30

a WS = weed suppression, NWC = no weed control, All = WS plus NWC plots.
b Three most common classes of seedling counts based on class intervals of 10.
c Median number per plot divided by estimated wetted area.
d Counts greater than 100 treated as 100 in mean and standard error analysis.
nd Not determined.

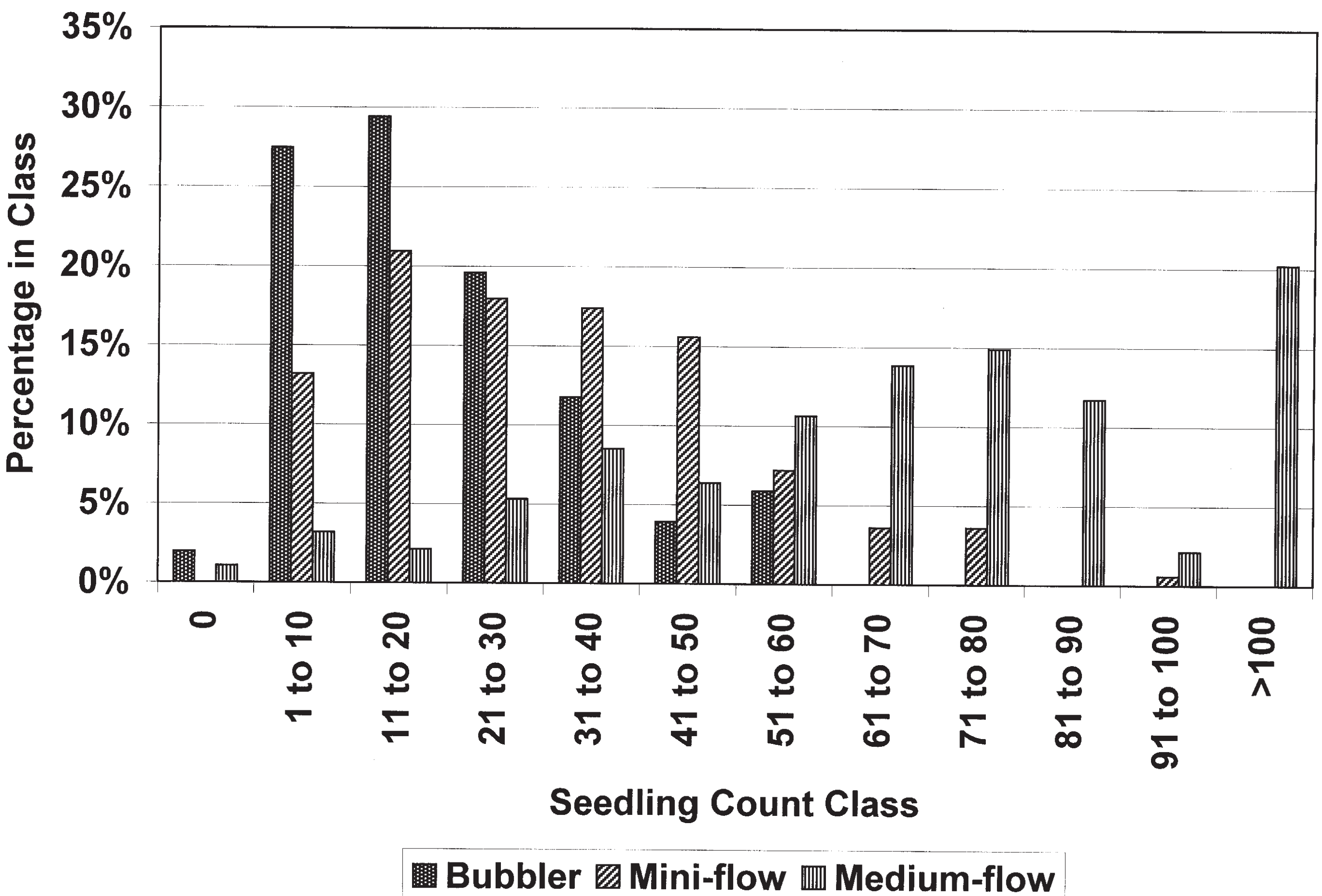

Figure 2—Rio Grande cottonwood seedling count distribution per plot for the 3 types of micro-irrigation emitters used at the study site located on the west side of the Rio Grande below Calabacillas Arroyo.

respectively. At the end of the first growing season many seedlings in the enclosure exceeded 0.3 m in height while some seedlings exceeded 0.6 m in height. With no weed control (outside the enclosure), the average seedling height was between 0.1 and 0.2 m. The plots with larger wetted areas appeared to have greater weed populations. These weeds in descending order of predominance were *Tamarix* spp., *Cenchrus longispinus*, and *Artemisia* spp. The reductions in survival and growth can not be related entirely to weed competition because the plots outside the enclosure suffered some disturbance by foot traffic and horses; this activity probably destroyed some seedlings and dislodged micro-tubing and emitters. The fencing prevented any obvious disturbance by people or pets to the plots receiving weed control.

The estimated wetted areas produced by the 3 emitter types are 2.71, 0.58, and 0.33 m^2 for medium-flow spitters, mini-flow spitters, and bubblers, respectively. The seedling density derived from these wetted areas are presented in table 2 using median seedling counts; the derived seedling densities are 55, 27, and 55 seedlings/m^2 for mini-flow spitter, medium-flow spitter, and bubbler plots with weed control. The corresponding water delivery rates are 24, 20, and 73 L/hr per m^2. This data might indicate that soil moisture could be limiting establishment on the medium-flow spitter plots. However, the calculated water delivery rate in the 1996 study at the Rio Grande Nature Center was 17 L/hr per m^2; therefore, sub-optimum irrigation interval and duration are probably more responsible for reduced density than water delivery rate.

The findings of this study after the first growing season include: 1) the small wetted area provided by bubblers was sufficient to establish seedlings in almost all plots; 2) the bubblers seemed to support less weed invasion than the other emitters and had appreciably lower flow rates than the medium-flow spitter; 3) weed control is critical for effective establishment because it provides higher seedling densities and more vigorous seedlings; and, 4) fencing might be required near areas with foot or horse traffic.

The intent of this study was not to determine minimum irrigation requirements for seedling establishment. However, high estimates of water use can be projected from the irrigation application rates of these emitters. The mini-flow spitters with the smallest flow rates used 345 m^3 of water to establish 5,300 seedlings; these data yield a water use of 65 L per seedling during the first growing season.

Economic Analysis of a Hypothetical Irrigation System

The high costs of most riparian restoration constrain the amount of disturbed areas that can undergo cottonwood regeneration. Pole planting costs of $2500 to $4000 per acre ($6200 to $9900 per ha) for cottonwood regeneration result from a recommended density of 100 trees per acre (250 trees per ha) assuming no mortality. The costs of irrigation and weed control used in the 1997 study can be extrapolated to an extended use of these methods for cottonwood regeneration of a large disturbed riparian area. The following analysis relies on many assumptions and can not account for many site characteristics, which could affect the engineering or the economics of the system. The intent is to provide a basis for evaluating the potential utility of the technology.

System Analysis of a Hypothetical Restoration Situation

The 6 hp pump used in the 1997 study is capable of providing 65 gpm (3900 gph) at 40 psi with a suction lift of 15’. A system composed solely of bubblers which deliver 3.6 gph at 10 psi could use up to 1080 bubblers (3900 gph/3.6 gph). The main line would have to consist of 2 inch ID pipe to accommodate 65 gpm. The mainline could be downsized to 1.5 inch ID toward the ends of the main line where flow rates would be less than 30 gpm. Spin clean filters would have to be installed in the pump discharge line to remove fine sand and silt from the irrigation water and minimize bubbler clogging. By assuming an acceptable density of cottonwood establishment of 100 trees per acre and assuming modest losses of young trees, 120 bubblers per acre could achieve the desired regeneration density. A total of 9 acres could be irrigated using these assumptions (1080 bubblers/120 bubblers per acre). By assuming a roughly rectangular disturbed area of 400 by 980 feet, a 2 inch main line 600 feet long would be required. Each lateral line could be 250 feet in length to provide a somewhat sinuous bubbler layout. If 30 bubblers were installed on each lateral (recommended maximum for uniform delivery with 0.5 inch ID tubing is 1.8 gpm), 36 lateral lines would be used for the 1080 bubbler allotment. If the bubblers are located within 10 feet of the lateral lines, the total lateral length (9000 feet) and bubbler corridor (20 feet) yield a potential irrigated area of 180,000 ft^2 or 46 percent of the total area. The micro-tubing that supplies each bubbler could be spaced about 8 feet apart on alternating sides of the lateral. If the length of micro-tubing varied between 5 and 10 feet with an average length of 7.5 feet, then 8100 feet of micro-tubing (0.125 inch ID) would be used.

The fixed costs of the irrigation system which are independent of the exact area or distribution system configuration include the 6 hp gasoline pump ($900), materials and installation of the 2” well point with a galvanized steel pipe length of 20 feet ($400), and miscellaneous parts including spin clean filters, suction and discharge hoses, and pressure gauge ($300). The variable costs dependent on system configuration include the main line 2 inch ID (600 feet - $180), main line fittings and fixed pressure regulators (36 lateral connections - $400), lateral line 0.5 inch ID polyethylene tubing (9000 feet - $675), lateral line fittings (36 laterals - $100), micro-tubing 0.125 inch ID (9000 feet - $160), and 1080 bubblers ($450).

The labor, travel, and supply costs required by the 1997 study which would be applicable to a typical restoration project are presented as well as an estimated multiplying factor based on the total area of the hypothetical site being 9 acres:

1) Application of herbicide $850 x 3 = $2550
2) Plot mowing and raking $725 x 5 = $3625
3) Install irrigation system $1075 x 2 = $2150
4) Irrigate at 3 hour intervals for 6 weeks $6400 x 1 = $6400
5) Irrigate every 4 to 5 days for 12 weeks $3600 x 1 = $3600
6) Supplemental hand weeding excluding routine weeding by irrigation system operator $1575 x 1 = $1575

Conclusions

These cost estimates yield the following summary results for a 9 acre cottonwood regeneration project for the first growing season:

1) Fixed equipment costs $1600
2) Variable irrigation supplies cost $1965 or $220/acre
3) Labor, travel, and weed control supplies cost $19900 or $2200/acre
4) Total $23465 or $2600/acre

The decisive factor in this analysis is the substantial costs resulting from weed control activities (33 percent of total) and irrigation operation (43 percent of total). The estimate of $2600/acre falls in the low range of estimated pole planting costs. Costs in future years should be small because only repair of pumping equipment and irrigation system components will be required, much less intensive weed control will be needed, and irrigation frequency will be greatly decreased (for example, every 2 weeks in second year). Pole planting also requires future costs for pest control and possible tree guard removal. Any appreciable reduction in the cost of weed control and irrigation would imply that micro-irrigation could be a cost effective method of cottonwood forest regeneration.

Planned Studies

Minimizing Water Use and Irrigation Labor

The micro-irrigation approach to be investigated in 1998 focuses on the use of micro-porous tubing (Tyvek,) as the water emission device. This tubing operates at very low pressures (2 to 6 psi) and at very low delivery rates (for example one liter per day per foot of micro-porous tubing). These factors should allow continuous operation of the irrigation system during the germination phase and the use of a water storage tank, which would only require periodic refilling. The storage tank could be sized with a 3 day capacity to prevent the need for irrigation labor over weekends. After the germination phase, the system could be manually turned on for a day, once or twice a week, to minimize the number of days the system needs attention.

Potential Weed Control Alternatives

Use of pre-emergence herbicides could be tested including: 1) particular chemicals with less adverse effects on cottonwood seedlings; 2) timing of application in relation to cottonwood germination and establishment; and, 3) rates of application. More effective nutrient additions by application of controlled release fertilizer might allow the cottonwood seedlings to better compete with weeds. The use of solarization could destroy the existing weed seed bank in the surface soil before cottonwood seed disseminates.

Conclusions

Micro-irrigation applied to xeric flood plain sites offers a method to establish cottonwood seedlings from natural seed dispersal. Micro-irrigation emitters providing small wetted areas (i.e., less than 1 m^2) allow the establishment of sufficient seedlings for probable long term survival of at least one sapling per irrigated spot. Areas with pedestrian or horse traffic may require temporary fencing to prevent disturbance of the seedlings or the irrigation system. Weed control has been a significant factor in providing high survival and growth rates for cottonwood seedlings. Labor for weed control and irrigation operation are the highest cost activities for a cottonwood regeneration project based on the present micro-irrigation technology. Potential improvements in micro-irrigation emitters and system design could significantly reduce irrigation labor costs and minimize water used for seedling establishment. Better weed control strategies and application of controlled-release nutrients could reduce long-term weed control costs.

Micro-irrigation technology is an additional tool for land managers confronted with riparian restoration projects. The use of a particular restoration technique (for example, natural flooding, flooding resulting from human intervention, pole planting, or micro-irrigation) will depend on the hydrologic, edaphic, economic, engineering, and jurisdictional constraints of the restoration site.

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