maximize rooting percentages while minimizing compound use. For the cost-conscious propagator, 5000 + 2000 is more highly recommended since the cost of NAA is one-fifth that of IBA.

Cuttings prepared from the lower portions of semi-hardened shoots root only slightly better than those selected from upper portions. While it is important to consider wood selection during cutting preparation, the choice of the proper rooting solution can have a greater impact on the rooting of *Rhaphiolepis indica* 'Jack Evans'.

Cuttings prepared from both the upper and lower portions of a shoot have the same relative responses to rooting solutions. Thus, the recommended solutions can be used for all cuttings which are derived from the semi-hardened portions of shoots.

LITERATURE CITED

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A 17-YEAR CASE HISTORY OF RESEARCH AND IMPLEMENTATION OF WATER RECYCLING ON CONTAINER NURSERY STOCK

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INTRODUCTION

This is a case history report on our progress in recycling irrigation runoff water over container ornamentals. In 1974, at the 15th Annual Meeting of IPPS, Western Region, I described a minor system of filtration of water for reuse. Later that year, we began more intensive research in the study of recycling water. This report describes the increase in knowledge gained since the original project was conceived, the culmination of this research, and the resulting construction of a 2.0 million gallon per day (MGD) (7571 m^3) water processing plant, and the results since we began recycling in 1979.

HISTORY

In 1971 we foresaw the need to control water pollution and to conserve water. In this respect we studied nitrogen (N) in the environment to determine ways to reduce its usage and we built a minor filtration plant with the thought of recycling both the water and the nutrients. We soon found that irrigation runoff could not simply be filtered and reused. Extensive research followed to study: 1) the effects of herbicides in a recycling system, 2) the effects of water treatment chemicals on plants, 3) chlorine and chloramine phytotoxicity, 4) the effectiveness of flocculation chemicals and polymers on clarification of water, 5) disinfection of water, 6) salinity build up, 7) disposal or reuse of sludge resulting from water treatment, 8) the efficacy of sedimentation, 9) the design of systems for water collection and pumping, 10) runoff and water consumption, 11) the change in elemental constituents of the runoff and processed waters, 12) hydraulic consideration in treatment, and 13) costs of treatment.

This research provided us with a wealth of information to reinforce our decision to recycle. The culmination was the construction of a water treatment plant in 1979. It consists of 7 sedimentation pits, an equalization reservoir, upflow clarifier, filter, blending pit, and storage reservoir. The water drains from sloping land areas into open ditches which congregate and flow into sedimentation pits. The purpose of the pits is to provide a small, quiescent water basin to allow the large particles, such as sand and silt to settle out and to remove floating debris by baffling. Water, laden with colloidal matter, overflows into pump pits, where pumps deliver the water to an equalization basin. From this point the water is pumped into a treatment building where flocculation and coagulant aids are added to the water to promote flocculation of the suspended clays. The pH is adjusted to fit our parameters for least solubility of the coagulants and greatest efficacy of flocculation. Clarification follows as a consequence of settling of the flocculated clay. The water is disinfected with monochloramine and filtration proceeds through dual media filters consisting of anthracite coal and sand. After polishing the water by filtration, it is blended at a ratio of approximately 1:1 with fresh, fortified water to make up the losses due to percolation and evaporation. The finished water flows into a 1.3 million gallon (4921 m^3) reservoir for reuse (Figure 1).

RESULTS

Water conservation. Recycling results in a 50% water conservation.

Fertilizer conservation. With a constant fertilization system, a 50% saving in water translates into a 50% recycling of fertilizer nutrients also. Since the water recycling is a closed system, nutrient leachates from container media are also recycled. This provides us with a considerable amount of nitrogen, potassium, calcium, magnesium, copper, zinc, manganese, and boron, negating the need to add these to the fresh, makeup water.

A side benefit is a change in the form of N that returns with the

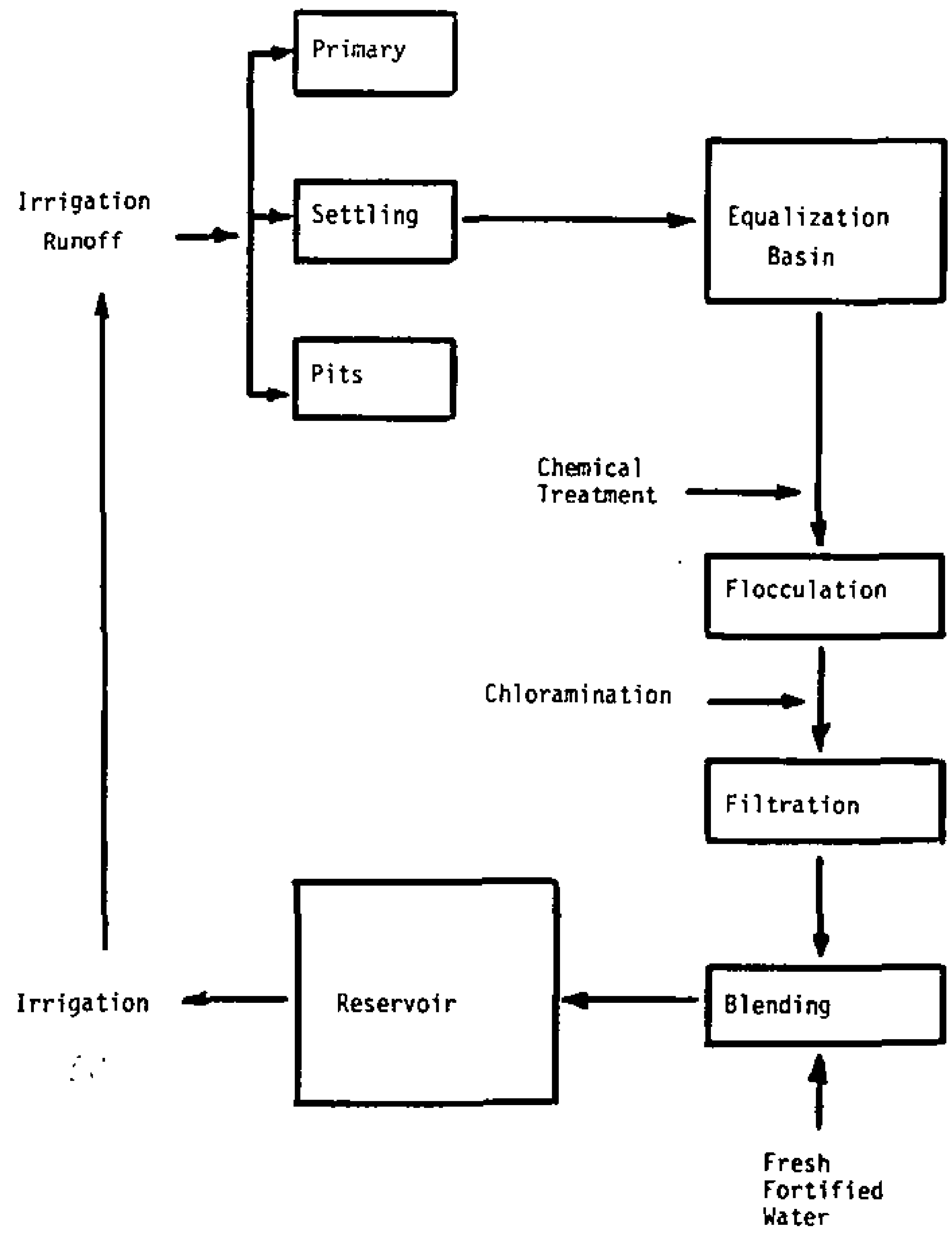

Figure 1. Schematic of water recycling and treatment.

runoff. Fresh water whould normally be fortified with ammonium nitrate, supplying 50% ammonium N and 50% nitrate N. The processed water results in a decrease in the ammonium N and an increase in the nitrate N as a consequence of nitration bacteria. Acid production in the soil is decreased, reducing the amount of corrective liming previously required to adjust the pH (Table 1).

Economics. The cost of water treatment has been determined to permit us to determine savings. It presently costs us $378 to process one million gallons (3785 m^3) (Tables 2 and 3).

Since our size permits us to obtain water treatment chemicals and fertilizers in quantity at lower costs, I calculated the costs and savings for a smaller grower, if he were to recycle. Based on lower quantity purchases, it would cost a smaller grower approximately $552 per million gallons (3785 m^3) to process water to the same degree of clarification. On the other hand, their saving in water costs and fertilizer are considerably more since they pay more for these items (Table 4). These savings do not allocate any costs of amortization of the capital expenditure.

Another added benefit we did not foresee initially was an 82% reduction in *Poa annua* seed germination. Recent chromatographic analyses of our processed water revealed we have a range of 0.002 to 0.038 mgl^{-1} of the various preemergence herbicides we use in our system. The herbicides we chose to use are based on our original studies with runoff from experimental plots treated with specific

Table 1. Percent change in constituents in processed runoff water.

Compared with fortified fresh water (blend water)	Constituent	Compared with reservoir water[z] (irrigation water)
140	H	100
−0.4	pH	−0.3
11	EC	7
−45	NH_4 N	−20
38	NO_3 N	8
0.6	Total N	−0.6
0	P	25
17	K	2
184	Ca	54
189	Mg	44
14	Fe	14
50	Cu	0
150	Zn	67
360	Mn	92
113	Na	55
3	B	−6
6	NTU[y]	−3

[z]50% processed runoff + 50% fresh fortified water
[y]Nephelometric turbidity units

Table 2. Cost to reclaim wastewater.

Agency	Source	Cost ($US) Acre-foot	10^6 gal.	1000 m^3
Los Angeles	Sewage	168	517	137
San Bernardino	Sewage	155	476	126
Monrovia Nursery	Irrigation runoff	123	378	100

Table 3. Allocation of costs of water treatment.

Item	Percent
Energy	47.8
Chemicals	38.4
Equipment maintenance	5.1
Labor	8.7
Total	100.0

herbicides. This processed water is diluted by 50% makeup water before recycling, resulting in an additional decrease in concentration of herbicides.

Water quality. Our fresh water supply is of excellent quality, being low in salinity, sodium, and boron. Even with the great amount of added nutrients, the concentration of all the elements falls into satisfactory levels for good quality water. Salinity increases on the average of 7% per cycle; however, the increase is at a decreasing rate since it is blended with lower salinity fresh, fortified water. The range of salinity may range from 0% in the winter to

Table 4. Potential savings of water and nutrients by the small grower using water recycling.

		$US per million gallons (3785 m^3)
Value of water		676[z]
Value of nutrients		790[y]
		1040[x]
	Range	1466 to 1716
Lowest value of water and nutrients saved		1466
Estimated cost of water treatment		−552
	Net saved	914

[z]Mean for six southern California counties
[y]Based on small quantity purchases of 5 tons or less per primary nutrient fertilizer; chloride formula
[x]Based on small quantity purchases of 5 tons or less; sulfate formula; assumed 200 mgl^{-1} N and 100 mgl^{-1} K

28% per cycle occasionally in the summer. The clarity of the water is very good, sometimes exceeding that of drinking water.

Chlorine gas is used as the disinfectant, immediately forming monochloramine because of the chemical nature of our water. Monochloramine is more stable to sunlight than chlorine. We maintain a residual monochloramine well below phytotoxic levels. Periodic MPN (most probable number) coliform tests and agar plate counts are made to determine efficacy of disinfection.

Plant response. Plant response was tested several times prior to recycling water. After the treatment plant was built, we conducted another, more extensive study of plant response. The study was conducted on 106 species. Plants grown under overhead irrigation with recycled water (50% processed runoff + 50% fresh, fortified water) were compared with plants grown under equal salinities of fresh, fortified, noncycled water. Visual evaluations were made on all 106 species and actual growth measurements were made on selected 31 species. Our mean growth for 106 species was 103% compared with 100% for fresh water (Table 5).

CONCLUSIONS

Water recycling appears to be a viable means of conservation of water and nutrients. Our commitment to recycling is indicated by continuing this practice in our Oregon location.

With the prospects of fresh water shortages with increasing populations, the trend is toward more water conservation throughout the United States.

VOICE: Question for Conrad Skimina. What was the total cost of your water recycling installation?

CONRAD SKIMINA: The plant cost 1.3 million dollars in

Table 5. Plant response to recylced[z] vs non-cycled water[y]

Plant	% Relative growth[x], recycled water
Actinidia chinensis	159[w]
Araucaria heterophylla	96
Arbutus unedo 'Compacta'	95
Berberis thunbergii 'Atropurpurea'	171
Brunfelsia pauciflora 'Floribunda'	85
Buxus microphylla var. *japonica*	100
Cedrus deodara	104
Cinnamomum camphora	94
Crassula argentea	120
Cryptomeria japonica 'Nana'	100
Cupressus sempervirens 'Glauca'	100
C. macrocarpa 'Donard Gold'	90
Ensete ventricosum	111
Gelsemium sempervirens	73
Hibiscus mutabilis 'Rubrus'	91
H. rosa-sinensis 'Ross Estey'	85
Juniperus chinensis 'Keteleeri'	120
J. chinensis 'Robust Green'	92
J. sabina 'Broadmoor'	100
J. scopulorum 'Pathfinder'	110
J. virginiana 'Cupressifolia'	100
Magnolia grandiflora	102
Mahonia aquifolium 'Compacta'	102
Nerium oleander 'Cherry Ripe'	95
Osmanthus heterophyllus 'Variegatus'	110
Pinus canariensis	95
P. thunbergiana	95
Platycladus orientalis 'Aureus Nanus'	84
Prunus caroliniana 'Bright N Tight'	160
Raphiolepis indica 'Enchantress'	94
Syzygium paniculatum	73

[z]50% processed runoff and 50% fresh fortified make-up water
[y]Fresh, fortified water
[x]Compared with 100% for non-cycled water
[w]Means of 14 replicates

1979. The rate of flow is 1400 gal. per min., approximately 2 million gal. per day.

VOICE: Conrad, what happens to the sludge residue left from your water treatment?

CONRAD SKIMINA: The sludge that settles out in the sedimentation pit is removed by a front end loader and hauled away to a dry land area.

VOICE: Gary, do you use spreader-sticker at all in your sprays at the nursery?

GARY PHIPPS: Yes, most of the time we do.

VOICE: Question for Bruce Lane. At what time in the year do you take your *Raphiolepis* cuttings?

BRUCE LANE: In southern California we take our cuttings from July to October, but mainly in September.