
Evaluation of User Friendly Drip Irrigation/Mulch Systems for Urban and Small Farm Specialty Crop Production (2001-2004)



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I. SITUATION

Water has become a major issue for both rural and urban communities in New Mexico. Ground water in the City of Albuquerque has been dropping at a rate of 1.3 to 2 feet per year (Uyttebrouck, 2000). Irrigation water for gardening in Santa Fe has been reduced to once a week for the last four years. Gardeners and growers are also competing for water with endangered species like the Silvery Minnow (Soussan, 2000).

Gardening has traditionally been a means of supplementing the food security for many low-income people in New Mexico. Over 17² percent of New Mexico residents experience food insecurity. Gardening is also popular with many affluent families, both as a source of fresh vegetables for better nutrition and as exercise for improved health. However, water usage for gardens and lawns can be substantial when using sprinklers or flood irrigation. Water usage was found to double in midsummer versus midwinter in an Albuquerque home with two people using sprinklers for a backyard garden and lawn from 1999 to 2001 (City of Albuquerque, 2001).

Most small farms in New Mexico are irrigated either by sprinkler, furrow, or flood irrigation, all of which are relatively inefficient. Vegetable producers are very concerned about the potential shortages of water for irrigation (Lamont Jr., 1991). The time of unlimited water is rapidly passing, and more efficient methods of irrigation and monitoring soil moisture must be evaluated.

II. CURRENT STATE OF KNOWLEDGE

Though drip irrigation has been proven to be one of the most efficient ways to irrigate, many gardeners have been intimidated by the complexity and expense of most commercial systems. New battery-controlled timers and drip lines sold by most hardware outlets have, however, made this innovation more user friendly (Blume and Kayko, 1998).

Gardeners have many questions regarding “off-the-shelf” drip irrigation systems including: Which timers are the easiest to use? Which timers and drip systems are the most

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durable? Which systems are the most affordable? Will salts build up in soils with season-long use of drip irrigation? Growers are also looking for simple tools that can be used to measure soil moisture in order to determine when to irrigate.

Organic mulches help cool the soil, conserve soil moisture, reduce annual weed production and return nutrients to the soil through decomposition (Dickerson, 1996). Maximum control of the soil environment, including water conservation, can be obtained with the use of drip irrigation under either organic or plastic mulches (Lamont Jr., 1991). Water savings using drip irrigation on crops can be as much as 80 percent when compared to other irrigation techniques (Bogle and Hartz, 1986).

Limited sites and personnel hamper the evaluation of drip lines, timers and mulches in the production of specialty crops at Agricultural Science Centers along the Rio Grande Basin in New Mexico. Evaluating the same systems by trained Master Gardeners would reduce labor costs and expand the number of sites and crops that could be evaluated. Bi-weekly contact with all cooperators by one project investigator would provide continuity for the entire project. Diffusion of this information by trained Master Gardeners in contact with other gardeners, by news releases, workshops, conferences and Extension publications would encourage the widespread use of this technology and a reduction in water use.

III. GOAL

To reduce water used in the production of vegetables, herbs and cut flowers in gardens and small farms along the Rio Grande Basin in New Mexico.

IV. OBJECTIVES

- A. Establish 13 Master Gardener/Experienced Gardener drip irrigation/mulch demonstration projects and evaluate these projects for water application efficiency in the production of vegetables, herbs and cut flowers in seven counties along the Rio Grande Basin in New Mexico.
- B. Evaluate various “off-the-shelf” battery timers used in the control of drip irrigation systems for “ease of use,” “reliability,” and “durability” over a three-year period at the above sites.
- C. Evaluate three types of “off-the-shelf” drip irrigation lines in combination with various organic mulches in the reduction of water applied to the various crops at the above sites.
- D. Evaluate the effectiveness of various organic mulches on water conservation, weed control and growth of various vegetables, herbs and cut flowers under drip irrigation.
- E. Evaluate the effects of drip irrigation on the accumulation of salts in the upper surface of the soil in mulched and non-mulched vegetable, herb and cut flower plots.

- F. Evaluate the efficiency of soil moisture sensors in measuring soil moisture in mulched and non-mulched drip irrigation plots.
- G. Establish two permanent herb/drip irrigation/mulch demonstration projects at the Santa Fe and Taos County Extension Services office grounds for the purpose of “hands-on” training for Master Gardeners and other clientele.
- H. Train 500 Master Gardeners on the benefits of using drip irrigation and various mulches in the production of vegetables, herbs and cut flowers.
- I. Document the number of Master Gardeners who have vegetable gardens, use compost and mulch, the types of irrigation techniques they use, and the types of vegetables they grow.
- J. Increase public awareness of the benefits of using drip irrigation and mulches to conserve water and enhance growth of specialty crops.

V. ACTION PLAN

- A. In October 2001, county Extension agents in seven counties along the Rio Grande Basin (Doña Ana, Valencia, Bernalillo, Sandoval, Santa Fe, Los Alamos, and Taos) were contacted to find Master Gardener and Non-Master Gardener (experienced gardeners) volunteers to participate in an urban drip irrigation project for vegetables, herbs and cut flowers. These counties were selected because they had Master Gardener programs.

Of the 14 sites selected in 2001/2002, only one cooperator dropped out of the program after the first year. Composite soil samples (6- to 8-inch depth) were taken from each site each year and sent to the soils lab at New Mexico State University for analysis. Fertilizer applications were based on these results. Irrigation water from each site was analyzed the first year to determine salt content.

Of the 13 sites that were monitored over the entire three years, two were run by Non-Master Gardeners, two by county agents (herb projects), one by the researcher, and the rest by Master Gardeners. Master Gardeners were heavily involved with the herb project in Santa Fe and to a lesser extent in Taos.

All projects were divided up into two equal mirror-image plots. An organic mulch was applied to one plot in each project after plants had emerged except Edgewood where it was applied at planting. Mulches varied by site and included straw, alfalfa, grass hay, compost, or newspaper. The second plot served as a “check” or “control” with no mulch. Both plots, at any particular location, contained the same varieties of vegetables, herbs or cut flowers. Water sources were either private wells or city water. Water pressures varied from 28 psi (Cerro) to 98 psi (Los Alamos Community Garden).

Two identical drip system plots were set up at each site. Drip lines and types of battery timers varied with location. During the second year, a digital timer was used for one plot and an analog timer was used for the second plot at each location.

During the third year, cooperators were allowed to use whichever timers they preferred from the previous years. The only exceptions were at Cerro, Taos and Santa Fe, where the same type of timer was used for both plots.

Each irrigation system consisted of a battery timer, antisiphon device (brass), pressure regulator (20 psi), “Y”-shaped screen filter, header line (1/2-inch black polypropylene) and drip line. After installation, each system was turned on for 15 minutes to calibrate the drip lines. Three rectangular shallow pans were placed under individual emitters or sections of soaker hose at random locations to collect water. The water was measured to determine the total output for each system.

Initially both systems at any particular site were set to come on for the same period of time up until the mulch was applied. The time of day each meter came on varied so meters would not compete with each other. After application of the mulch, the mulch plot was usually programmed to come on about half as often as the check plot up until frost. The exact intervals varied with location and time of year.

Most cooperators planted mixed vegetables in their plots. Herb gardens were planted at both the Santa Fe and Taos County Extension office grounds. Planting generally began in early April in Las Cruces and ended in early to mid-June in Cerro. All plots were maintained by the cooperators throughout the growing season, including weeding, insect control, and harvesting. Each project was visited by the researcher every two to three weeks during the growing season. Logs (calendars) were kept by the cooperators on most activities in the garden, including adjustment of timers and rain records. Logs were collected at the end of the season to determine water application amounts for each plot, rainfall amounts and weeding activities.

B. Five “off-the-shelf” battery timers were initially purchased for the project. Each was first evaluated by the researcher to determine whether they would be suitable for the project. The meters included:

1. DIG Model 7010
2. Nelson Easy-Set 3
3. Orbit Model 62015/62415
4. Orbit Model 62001/62401
5. Gilmore Model 9400

The DIG meter was immediately eliminated since it would not completely shut off. The other four were installed randomly at the various locations throughout the state. After approximately a month, the Easy-Set 3 meters were replaced by Gilmore meters due to a number of malfunctions. During the second year, a Raindrip Model R672C was added to the mix.

Each cooperator was assigned one set of meters (same model) to evaluate the first year. Initially, the meters were installed and programmed by the researcher. Cooperators, however, were given written directions for the meters and were asked to adjust them when necessary. In September, cooperators were sent directions to cut back the irrigation days by reprogramming their meters. Two weeks later the meters were checked by the researcher to determine if the meters were programmed correctly. An evaluation form was sent out at the end of the season to each cooperator to list the pros and cons of their assigned meters. Cooperators were asked to consider “ease of use,” “reliability,” and “durability” of the meters.

The second year, cooperators were allowed to keep one of the meters from the previous year. The other meter was kept as a spare. Each was given a new meter to evaluate. Depending on the meter from the previous year, the new meter was either an analog or digital meter so that the cooperator had one of each. Both were evaluated at the end of the season using the above evaluation criteria.

During the third year, cooperators were allowed to select any of the meters they had evaluated in the previous years. Inherently it was a judgment call indicating which meter they felt was best.

C. Three “off-the-shelf” drip irrigation lines were purchased for this project:

1. Dura-Flo Jr. ¼-inch dripper line (6-inch emitter spacing)
2. Dura-Flo Jr. ¼-inch dripper line (12-inch emitter spacing)
3. 5/8-inch soaker hose

Each cooperator was randomly assigned one of the above types of drip line and was asked to evaluate the pros and cons of the line (same evaluation form as above). Cooperators were also asked how well the drip lines worked in combination with the mulch in conserving water. Three of the four cooperators assigned the 12-inch emitter spacing drip line were changed over to the 6-inch emitter spacing drip line during the second year, as well as one of the soaker line cooperators.

D. Various organic mulches were used in this project: grass hay, alfalfa hay, straw, newspaper and compost. They were each evaluated by the cooperators at the end of each year for abilities to conserve moisture, control annual weeds and effect growth.

E. A soil analysis was used to determine the salt content (electrical conductivity or E.C.) of each soil sample for each experimental site early in the first growing season (2002). The salt content of irrigation water used at each site was determined with a water analysis. To determine salt buildup on the surface of the soil at each site due to the use of drip irrigation, composite soil samples were collected from the upper inch of soil in both plots at each site directly under the drip line and 8 to 10 inches to the side of each drip line (edge of water line). This was done in mid-summer and at frost in the fall.

The soil samples were allowed to air dry in a garage for 2-3 weeks. They were then sifted through a kitchen colander to remove rocks and other larger debris. A 1/3-pound sample was placed in a plastic cup. Distilled water was added and stirred into the sample to make a saturated paste. The sample was then allowed to set for a few minutes. Each sample was then evaluated for total soluble salt content (g/l) using a PET 2000 Dual Purpose E.C. meter. Two readings were made for each sample and averaged.

F. At each location in 2003, two Watermark soil moisture sensors were soaked in water for eight hours, dried, and were soaked again for eight hours. At planting time, a six-inch deep hole was dug in the soil near one of the drip lines in each plot (same location in each plot) using a narrow trowel. The holes were filled with water and allowed to drain. One sensor was placed in each hole and covered with a slurry of

mud made from soil from the hole. The lines to the sensors were tied to rebar and readings (centibars) were collected periodically throughout the season. Sensors were removed the following spring.

In 2004, 24 Watermark soil moisture sensors were used in each herb experiment in Santa Fe and Taos. Sensors were soaked in water for eight hours, dried and were soaked again for eight hours. Two holes (6 and 12 inches deep) were drilled into the soil around select herbs (Echinacea, Peppermint, Mother of Thyme, Dwarf Curry Plant, Munstead Lavender and Winter Savory) with a one-inch diameter auger in each of the treatment plots (check and mulch). Holes were approximately 4-6 inches from the base of plants. Holes were filled with water and allowed to drain. The sensors were then placed in each hole and covered with a slurry of mud made from the same holes. The lines to the sensors were tied to rebar and readings (centibars) were collected throughout the season.

- G. Two permanent herb gardens were established at the Santa Fe and Taos County Extension Service office grounds in 2002. Each project had two mirror-image plots with various annual and perennial culinary and ornamental herbs. Annual herbs planted in 2002 were replaced with other perennial herbs in 2003. Perennial herbs that died of winter kill in 2002 and 2003 were also replaced with other perennial herbs in 2004. One plot was mulched with grass hay and the other plot was not mulched. Besides being used as a drip irrigation project, the gardens were used as permanent herb demonstration projects for teaching purposes. Most herbs planted at Taos were also planted at Santa Fe and were evaluated together to determine how well they survived. Data were collected on growth, flowering and yields.
- H. The traditional Master Gardener training program for vegetables was modified in the spring of 2002 to include more information on water conservation in the home vegetable garden. To determine how much of this information was immediately retained by Master Gardeners--after passively listening to a three-hour slide program on vegetable gardening that included the water conservation information--pre- and post-tests were administered to the participants. They had been asked not to take notes or to refer to notes during the program or when taking the test.

The test consisted of 10 questions that were either "fill-in-the-blank" or multiple choice (more than one correct answer was possible). The questions covered water, salts, nutrients and diseases affected by water. The test was administered to both Master Gardener trainees and veteran Master Gardeners. The test was administered annually at all Master Gardener programs for three years.
- I. A survey was distributed to all vegetable gardeners in the above Master Gardener programs to determine what types of irrigation techniques they used, whether they used mulches and compost, and what types of mulches they normally used. Information was also collected on what types of vegetables they typically planted.
- J. The public was made aware of the benefits of using drip irrigation and mulching to conserve water and enhance growth of specialty crops through Master Gardener training programs, garden programs, publications, workshops, conferences, tours, field days, newspaper articles and newsletters.

VI. RESULTS

- A. Eight of the 13 cooperators (last two years) in this project were Master Gardeners, two were Non-Master Gardeners (experienced gardeners), two were county Extension agents, and one researcher (table 1). Four of the cooperators used city water while the rest had wells. Individual plot sizes varied from 72 square feet (Edgewood) to 370 square feet (Cerro).

The amount of water applied to the check plots in 2002 (tables 2 and 3) varied from 2.2 acre-feet (Los Alamos locations 3 and 5) to 10.1 acre-feet (Bosque). The mulch plots varied from 1.6 acre-feet (Los Alamos location 5) to 7.0 acre-feet (Bosque). Water savings as a result of using mulches ranged from 7.3 percent (Los Alamos location 3) to 50.8 percent (Albuq./San Pedro). The average water savings using the mulches was 26.3 percent (did not include the Albuq./Heights location). Greater water use tended to be associated with use of soaker hoses and longer growing seasons. One exception was in Cerro, where the system was left on most of the day

The amount of water applied to the check plots in 2003 varied from 1.3 acre-feet (Cerro) to 26.9 acre-feet (Bosque, tables 2 and 3). The mulch plots varied from 1.0 acre-feet (Cerro) to 20.1 acre-feet (Bosque). Water savings, as a result of using the mulch, ranged from 18.2 percent (Santa Fe) to 53.8 percent (Las Cruces). The average water savings using the mulches was 31.3 percent (excludes Bosque). The heavy water applications at Bosque were due

Table 1. Project locations, types of cooperators, water sources and individual plot sizes. New Mexico, 2003-2004.

Location	Type of Cooperator	Water Source	Plot Size (Ft. ²)
1. Cerro	Non-Master Gardener	Well	370
2. Taos	Agent	Well	225
3. L.A. Com. Garden	Master Gardener	Well	128
4. L.A. Com. Garden	Master Gardener	Well	128
5. Los Alamos	Master Gardener	City	183
6. Santa Fe	Agent/Master Gardeners	Well	350
7. Rio Rancho	Master Gardener	City	297
8. Albuq./San Pedro	Master Gardener	City	245
9. Albuq./Heights	Researcher	City	180
10. Edgewood	Non-Master Gardener	Well	72
11. Belen	Master Gardener	Well	285
12. Bosque	Master Gardener	Well	132
13. Las Cruces	Master Gardener	Well	135

Table 2. Project locations (northern New Mexico), type of drip, water applied and water savings, 2002 – 2004.

Location	Date	Drip ²	Water Applied (Acre-Feet)		% Water Savings with Mulch ¹
			Check	Mulch	
1. Cerro	2002	12	5.8	5.1	13.2
	2003	12	1.3	1.0	22.7
	2004	12	0.9	0.8	18.2
2. Taos	2002	6	4.1	3.2	22.1
	2003	6	2.3	1.8	23.7
	2004	6	2.2	1.6	27.9
3. L.A. Com. Garden	2002	6	2.2	2.1	7.3
	2003	6	1.7	1.2	32.0
	2004	6	1.4	1.2	18.6
4. L.A. Com. Garden	2002	Soaker	3.4	2.7	18.4
	2003	Soaker	4.7	2.6	44.7
	2004	Soaker	3.5	4.2	--
5. Los Alamos	2002	6	2.2	1.6	27.8
	2003	6	1.7	1.4	22.4
	2004	6	1.3	0.9	35.9
6. Santa Fe	2002	6	3.2	2.4	23.3
	2003	6	2.0	1.6	18.2
	2004	6	2.2	1.6	27.4

¹Based on gallons of water applied to each plot

²Emitter spacing (6 or 12 inches) or soaker hose

to new soaker hoses that had no water reduction washers (pressure reducers) in the female ends of the hoses. The water tended to go straight down through the loose soil that made up the beds and was not noted by either the researcher or cooperator. The older hoses at the same site (second figure) tended to put out less water due to salt accumulation imbedded in the hoses from the previous year which restricted, water flow.

The amount of water applied to the check plots in 2004 varied from 0.9 acre-feet (Cerro) to 8.5 acre-feet (Albuq./San Pedro, tables 2 and 3). The mulch plots varied from 0.8 acre-feet (Cerro) to 6.6 acre-feet (Albuq./San Pedro). Water savings as a result of using the mulch ranged from 14.2 percent (Rio Rancho) to 51.4 percent (Bosque). The average water savings using the mulches was 29.3 percent (excludes Los Alamos location 4 and Belen).

Of the 12 original sites that participated in the three-year project (excludes Albuq./Heights), only two sites showed no improvement in water savings over the three-year period (Albuq./San Pedro and Los Alamos location 4) when comparing check plot to check plot or mulch plot to mulch plot at each site. Reduction in water use over the three-year period at the other sites varied from 31.2 percent (check) and 33.3 percent (mulch) at Santa Fe to 84.4 percent (check) to 84.3 percent (mulch) at Cerro. Most of this improvement was associated with experience gained by the cooperators over the three-year period in programming their timers to deliver the optimum amount of water needed by their plants at various times during the growing season.

Rainfall varied from 0 inches (four sites) in 2003 to 7.9 inches (Edgewood) in 2004. 2003 tended to be the driest year (2.0 inches average across all sites), while 2004 was the wettest (4.5 inches average). The dry, hot weather of 2003 was very detrimental to crop growth at most locations during the year.

- B. The Dig Model 7010 timer was pre-tested before the project was initiated in 2002. After failing to shut off completely, it was eliminated. The Easy-Set 3 timer was initially set out at four locations but was later eliminated due to multiple failures at three sites within the first month. It was replaced by the Raindrip R672C timer in 2003.

The four remaining timers (two analog and two digital) were evaluated each year for “reliability” and ease of understanding of the “instructions” by the cooperators. Cooperators only evaluated the timers they were assigned. Evaluations for each timer were combined and averaged for the three-year period and then compared (table 4).

The analog timers tended to be easier to understand in terms of instructions, since only two rotary dials needed to be adjusted to set the program. One dial set the “watering interval” or “frequency” and the other set the “watering duration.” Depending on the timer, intervals varied from “once an hour” to “once a week.” Assuming the “once-an-hour” option was chosen, there was no way to turn the timer off at night. Durations varied from one minute to two hours.

The digital timers tended to be harder to understand in terms of instructions, particularly the Gilmore timer. The Orbit 62001 was somewhat easier, particularly after cooperators became more familiar with it. The digital timers were a little more flexible in terms of watering intervals. The timer could be programmed to come on once every day, on any particular day or days of the week, every second or third day

of the week. There were four separate program options, so the timer could be programmed to turn on at four separate times during the day to eliminate any excessive watering at night.

The digital timers were also a lot more flexible in terms of watering duration. The timers were not limited to preset times on a dial. Since the timers were set in increments of one-minute digits, the timer could be set to come on for 7, 8, 13 or even 61 minutes. The maximum time for the Orbit 62001 model was up to 360 minutes.

Before setting an irrigation program for a digital timer, a “reference” clock had to be set with the present time of day and day of the week. The program would then refer back to this clock when it was scheduled to engage. The reference time for each analog timer was determined at the time of day it was originally set. For example, if the cooperators wanted the timer to begin irrigating at 4 a.m. every 24 hours, the cooperators would have to physically set the program at 4 a.m. the first time. The program would not engage until 24 hours later at 4 a.m. This tended to be a nuisance if the program had to be changed very often during the growing season.

Both analog timers were relatively cheap compared to the digital timers.

However, the analog timers, particularly the Raindrip 672C timer, tended to fail more times than the digital (Gilmore) timers. The Orbit 62001 Digital timer was the most expensive timer but was also the most reliable. Not one of these timers failed over the three-year period.

Table 3. Project locations (central/southern New Mexico), type of drip, water applied and water savings, 2002–2004.

Location	Date	Drip ²	Water Applied (Acre-Feet)		% Water Savings with Mulch ¹
			Check	Mulch	
7. Rio Rancho	2002	6	7.8	7.1	8.9
Rio Rancho	2003	6	8.8	5.0	43.4
Rio Rancho	2004	6	3.2	2.8	14.2
8. Albuq./San Pedro	2002	12	8.4	4.1	50.8
Albuq./San Pedro	2003	6	8.1	6.2	22.9
Albuq./San Pedro	2004	6	8.5	6.6	22.3
9. Albuq./Heights	2003	6	3.1	2.2	29.1
Albuq./Heights	2004	6	3.3	2.2	34.4
10. Edgewood	2002	Soaker	5.9	3.0	48.7
Edgewood	2003	6	3.4	1.9	43.8
Edgewood	2004	6	2.3	1.4	41.3
11. Belen	2002	6	4.3	3.1	28.5
Belen	2003	6	2.4	1.9	19.1
Belen	2004	6	1.6	1.7	--
12. Bosque	2002	Soaker	10.1	7.0	30.7
Bosque	2003	Soaker	26.9 ³ / 6.1 ⁴	20.1 ³ / 6.4 ⁴	25.5/--
Bosque	2004	Soaker	4.0 ³	1.9 ³	51.4
13. Las Cruces	2002	6	9.2	5.9	36.1
Las Cruces	2003	6	12.4	5.7	53.8
Las Cruces	2004	6	3.8	2.6	30.3

¹ Based on gallons of water applied to each plot

² Emitter spacing (6 or 12 inches) or soaker hose

³ New soaker hose

⁴ Old soaker hose

Table 4. Evaluations of reliability and instructions of two analog and two digital battery timers. New Mexico, 2002-2004.

Battery Timer	Type	Rating ¹	
		Reliability	Instructions
Orbit 62015	Analog	3.6	3.6
Orbit 62001	Digital	3.8	3.5
Gilmore 9400	Digital	3.3	3.1
Raindrip R672C ²	Analog	2.7	3.5

¹ Rating: Excellent (4), Good (3), Fair (2), Poor (1)

² Evaluated for only two years

Table 5. Project locations and effects of organic mulches on weed control and water conservation. New Mexico, 2002-2004.

Location	Mulch Rating ¹	
	Weed Control	Water Conservation
1. Cerro	2.7	3.0
2. Taos	3.3	4.0
3. L.A. Com. Garden	2.0	2.3
4. L.A. Com. Garden	2.3	2.5
5. Los Alamos	2.7	4.0
6. Santa Fe	3.0	4.0
7. Rio Rancho	3.0	2.7
8. Albuquerque/San Pedro	4.0	3.3
9. Albuquerque/Heights	3.7	3.7
10. Edgewood	4.0	4.0
11. Belen	1.0	3.3
12. Bosque	3.3	3.7
13. Las Cruces	3.3	3.0

¹Rating: Excellent (4), Good (3), Fair (2), Poor (1)

One minor problem with the digital timers was the plastic face. It was often hard to read the timer due to the glare reflecting off the surface when the sun was to the wearer's back.

- C. Three drip lines were used in this project. The Dura-Flo Jr. ¼-inch dripper line (12-inch emitter spacing) was originally established at four locations. Although cooperators rated the drip line as good to excellent, the ratings were mostly based on the reliability of the imbedded emitters which didn't clog and had uniform patterns of water distribution. It took, however, 2-3 times longer for water distribution (soaking) patterns to merge with neighboring emitters with the 12-inch spaced emitters than it did the 6-inch spaced emitters, particularly on sandy soils. This generally resulted in greater water applications. The 12-inch spaced emitter line was limited to Cerro the following two years.

The Dura-Flo Jr. ¼-inch dripper line (6-inch emitter spacing) was rated by cooperators as good to excellent in terms of reliability. It was rated as the best line for vegetable production due to its uniform water distribution pattern. The water patterns generally merged with each other after only one hour of water application. During the third year, however, the emitters at the ends of the lines started to clog up with salt. Depending on water quality, the lifetime of this type of emitter line is probably two to three years.

Cooperators rated the 5/8-inch soaker hose as good to excellent in terms of reliability. The hose was excellent for germinating seed because the water distribution pattern was a solid line as soon as water was applied. At the beginning of the season, water could be applied for a few moments several times a day to keep seeds wet, using limited amounts of water. Amounts could be increased over time as plants grew. This was not possible with the 6-inch spaced emitter, since it took at least an hour for the water patterns to merge.

Water distribution for the soaker hose was, however, somewhat uneven. They also tended to apply more water than the Dura-Flo Jr. lines, especially under higher

Table 6. Project locations and salt concentrations (1-inch depth) below and to the side (water line) of mulched and non-mulched (check) drip irrigation lines. New Mexico, August, 2002.

Location	Grams of Soluble Salt/Liter of Soil			
	Check		Mulch	
	Water Line	Below Drip	Water Line	Below Drip
1. Cerro	.71	.30	1.08	.31
2. Taos	.62	.63	.73	.40
3. L.A. Com. Garden	.52	.39	.54	.45
4. L.A. Com. Garden	1.07	.51	1.44	.52
5. Los Alamos	1.08	.22	.47	.38
6. Santa Fe	.60	.46	.46	.41
7. Rio Rancho	1.38	.26	1.41	.33
8. Albuquerque/San Pedro	1.66	.31	1.60	.61
9. Albuquerque/Heights	.29	.29	.42	.43
10. Edgewood	.56	.33	.51	.32
11. Belen	1.56	.33	1.35	.45
12. Bosque	.97	.32	.83	.44
13. Las Cruces	.46	.28	.97	.28
Average	.88	.36	.91	.41

pressures (20 psi). It helped to have water reduction washers in the female connectors to limit the flow of water. Over time, the hoses tended to clog with salt and kinked in tight corners. Most cooperators, however, felt they were easier to use.

- D. Cooperators rated the organic mulches as poor to excellent in terms of weed control (table 6). Poorer results were noted the first year in some of the plots where a grass mulch had been applied that was contaminated with weed seed. Water conservation was rated as fair to excellent (table 5). In many cases, the organic mulches tended to retard growth of most crops, particularly in colder areas of the state. This may have been the result of cooling of the soil. Many of the herbs in Taos and Santa Fe, however, responded quite favorably to the organic mulches, while others were retarded.
- E. The average numbers of grams of soluble salt per liter of soil (1-inch depth) collected directly below the drip lines in the check and mulch plots (August, 2002) were over 50 percent lower than the salts directly below the water lines (wetting boundary) for both plots (table 6). This indicated salts in the soil and water were accumulating at the water lines. Results were similar when soil samples were analyzed in October/November (table 7). The average overall salt content for all plots in October/November dropped by 27 percent. This would seem to indicate that either rainfall or continued irrigation leached salts down below the 1-inch soil depth as the season progressed.
- F. The Watermark Soil Moisture Sensors worked quite well at all plot locations in 2003. Their usefulness, however, was limited since they could not be checked every day by the researcher to determine the optimum time to irrigate.

At the herb plots in both Santa Fe and Taos in 2003, sensors were placed near established Lemon Balm plants and New French Lavender plants in both the check and mulch plots. Over the summer, at both locations in both plots, the sensors in the

Table 7. Project locations and salt concentrations (1-inch depth) below and to the side (water line) of mulched and non-mulched (check) drip irrigation lines. New Mexico, October/November, 2002.

Location	Grams of Soluble Salt/Liter of Soil			
	Check		Mulch	
	Water Line	Below Drip	Water Line	Below Drip
1. Cerro	.30	.21	.52	.30
2. Taos	.62	.33	.67	.32
3. L.A. Com. Garden	.77	.31	.68	.40
4. L.A. Com. Garden	.93	.50	.56	.43
5. Los Alamos	.27	.20	.56	.21
6. Santa Fe	.29	.28	.96	.34
7. Rio Rancho	.39	.38	.59	.27
8. Albuquerque/San Pedro	.69	.29	1.08	.70
9. Albuquerque/Heights	.56	.22	.77	.44
10. Edgewood	.59	.44	.49	.43
11. Belen	.76	.36	.48	.25
12. Bosque	.34	.22	.45	.34
13. Las Cruces	.71	.18	.86	.20
Average	.56	.30	.67	.36

Lemon Balm plots always indicated less soil-water than in the French Lavender plots, indicating more water use near the Lemon Balm plants.

In 2004, moisture readings (centibars) for all moisture probes at both herb project locations in Taos and Santa Fe were generally taken at least once a week throughout the growing season. Plots were irrigated when at least two of the probes reached 20 to 30 centibars. Moisture readings for each herb depth and mulch treatment were averaged across the entire season. Echinacea (28 centibars) and peppermint (22) tended to use more water than other herbs in Taos, while peppermint (28), Winter Savory (26) and Mother of Thyme (25) tended to use more water in Santa Fe. Moisture readings at the 6-inch depth tended to be slightly higher than at the 12-inch depth.

Some plots, at both locations early in the season, showed abnormally high moisture readings. This was due to emitters on the end of the drip lines that had started to plug up with salt. This plugging of the emitters at the end of the lines also happened at other locations. Although the emitters at the ends of these lines were replaced, it indicated that the life expectancy of the lines is probably two years if there's much salt in the water.

- G. A total of 47 annual and perennial herbs were evaluated over three years in the mirror-image herb/drip irrigation project in Santa Fe. Forty-five herbs were tested in the project in Taos. The majority were culinary herbs. Data were collected on growth, yield, flowering and winter kill (perennials). The projects were used to specifically train Master Gardeners and other clientele on how to set up a drip irrigation system. A total of six workshops were conducted over the three-year period at both sites. Herbs were all marked with plastic stakes for easy identification by clientele visiting the sites. Master Gardeners maintained plots in Santa Fe and conducted monthly educational programs on specific herbs in 2004. The project will be terminated in the fall of 2005.

Table 8. Pre-test, post-test, and gain scores for Master Gardener irrigation/vegetable gardening training program. New Mexico, 2002–2004.

Year	# M.G. Programs	# Participants	Pre-Test Scores (%)	Post-Test Scores (%)	Difference	Gain Scores (%)
Trainees						
2002	12	216	53.3	75.5	22.2	41.7
2003	11	212	40.9	74.1	33.2	81.2
2004	10	185	38.8	74.7	35.9	92.5
Total	33	613	Avg. 44.6	Avg. 74.8	Avg. 30.2	Avg. 67.7
Veterans						
2002	12	44	59.3	78.8	19.6	33.1
2003	11	37	54.0	80.3	26.3	48.7
2004	10	38	53.4	78.7	25.3	47.4
Total	33	119	Avg. 55.8	Avg. 79.3	Avg. 23.5	Avg. 42.1

H. A total of 36 Master Gardener programs on irrigation and water conservation in the home vegetable garden were conducted from 2002–2004. Three of the programs were conducted on the Navajo reservation (Arizona) and were not included in the testing procedure. A total of 944 Master Gardeners participated in the training, but only 732 trainees and veteran Master Gardeners (33 programs) took the pre- and post-tests that were administered (table 8). Over the three-year period, pre-test scores for trainees averaged 44.6 percent while post-test scores averaged 74.8 percent. Gain scores averaged 67.7 percent. Pre-test scores for veterans were approximately 11 points (55.8 percent) higher than for trainees, probably because most veterans had some of the training in the past. Post-test scores (79.3 percent), however, were only about five points higher than for trainees. Gain scores for veterans (42.1 percent) were lower than for trainees since their initial pre-test scores were higher. Post-test scores for all participants were considered relatively high since participants had no study time and were not allowed to refer to notes.

I. Approximately 64 percent of the gardeners who participated in the Master Gardener training program claimed to be vegetable gardeners, 58 percent of whom also claimed to be organic, indicating both the importance of vegetable gardening and organic practices in the Master Gardener program. Of those who claimed to be vegetable gardeners, 81 percent used some type of mulch, 80 percent used compost, and 69 percent made their own compost, again indicating the importance of these topics in the training program. In terms of popularity as a mulch, 28 percent of the participants used straw, followed by grass clippings (19 percent), wood chips (16 percent), compost (14 percent), plastic (12 percent) and leaves (9 percent).

Approximately 57 percent of the participants used some type of drip irrigation technique, while 30 percent used sprinklers, 22 percent furrow and 19 percent flood. Some used two or more different types of irrigation systems.

Nearly 97 percent of the participants grew tomatoes. It was followed in popularity by squash (60 percent), green beans (44 percent), bell peppers (44 percent), lettuce (36 percent), cucumbers (33 percent) and chile (30 percent).

- J. The public was made aware of the benefits of using drip irrigation and mulching techniques to conserve water in the production of herbs and other specialty crops through five publications, six newspaper articles, seven newsletters, one radio program, one TV program, 16 garden programs, 36 Master Gardener programs, two seminars, four workshops, eight tours, thirteen conferences and one field day.

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