Evaluation of an Integrated Limited Irrigation Water Catchment System for Vegetable Production

Cooperative Extension Service • Circular 568
College of Agriculture and Home Economics

CONTENTS

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George W. Dickerson[1]

Water has become a major issue for both rural and urban communities in New Mexico. The majority of cropland along the Rio Grande, Pecos and San Juan rivers receives less than 10 acre-inches of precipitation per year (USDA-NRCS, 1999). Cropland on the High Plains of New Mexico averages between 16 and 24 inches of precipitation. Part of this precipitation may come in the winter and be lost to evaporation or come in the form of flash floods during the summer and be lost to runoff.

It is estimated that New Mexico consumes 1.7 times its yearly replenishment of ground and surface water, the majority of which is used by agriculture (Mapel, McGuckin, Lansford, and Sammis, 1985). The result is the mining of water that is not replaced. Urban populations and industry also are demanding a greater share of water resources.

In arid regions of the United States, it is estimated that vegetable crops require at least 2 acre-inches of water per week during the growing season to produce maximum yields (Lorenz and Maynard, 1997). Depending on crop maturity, soil type, average monthly temperatures and irrigation techniques, many vegetables may require over 3 acre-feet of water per year to produce optimum yields.

WATER CONSERVATION TECHNIQUES

To address the issues of declining water reserves and greater demands for water by urban communities in New Mexico, many techniques have been developed to more efficiently deliver water to crops or to help conserve water. Lazer leveling, drip irrigation, alternate-row irrigation techniques, and the use of plastic mulches have become popular with many growers. Drip irrigation, mulches, and xeriscaping techniques are popular in home landscapes and gardens.

Mulches help conserve moisture by reducing soil moisture evaporation (Dickerson, 1996). Mulches also ensure a more even moisture supply and reduce or prevent weed growth. Black polypropylene mulch also can help warm the underlying soil by as much as 5°F at a 2- inch depth compared to unmulched soil (Lamont, 1998). This can be an asset in cooler soils in northern New Mexico for warm-season crops or where earlier crop production is desired. Some plastic mulches, however, tend to break down by ultraviolet light and can become a trash problem in the field by the season's end.

A sandy soil's water-holding capacity can be increased by using compost as a soil amendment (Dickerson, March 1999). Compost also will increase a sandy soil's cation exchange capacity (ability to retain nutrients and release them to plant roots as needed). Compost will help improve the aeration and drainage of clay soils. It is a limited source of nutrients and has been shown to suppress soilborne diseases both in the field and in the greenhouse (Dickerson, June 1999; Hoitink, 1993).

In 1992, the City of Albuquerque dedicated a new state-of-the-art municipal composting facility to address the problems of landscaping wastes (woody fraction) and biosolids (sludge) that make up a significant portion of the solid waste stream deposited in the local landfill. The biosolid compost produced at this facility has been shown to be an effective soil amendment both in the field and in the greenhouse (Dickerson, June 1999). The biosolid compost also was found to have a natural fungicidal effect on the control of "damping off" on seedling chile and snapdragons. Optimum applica-

[1]Extension Horticulture Specialist, Extension Plant Science Department, New Mexico State University, Las Cruces, New Mexico

Table 1. Compost and cross-linked polyacrylamide polymer treatments at eight sites in New Mexico, 1997.

Location	Compost (T/A)	[1]Polymer (lbs/1000 ft^2)	Comments
Garfield	23.2	75, 0 (I, NI)	Unscreened compost
Garfield	0	75, 0 (I, NI)	— —
Zuni	25.6	75, 0 (I, NI)	— —
Zuni	0	75, 0 (NI)	Non-compost site was no-till
Portales	33.7	75, 0 (I, NI)	— —
Portales	0	75, 0 (I, NI)	— —
Arroyo Seco	11.6	75, 0 (I, NI)	— —
Arroyo Seco	0	50, 0 (I, NI)	— —
Lyden	23.8	50, 0 (I, NI)	— —
Lyden	0	50, 0 (I, NI)	— —
Aztec	25.6	50, 0 (I, NI)	— —
Aztec	0	50, 0 (I, NI)	— —
Roswell	22.1	50, 0 (I, NI)	— —
Roswell	0	50, 0 (I, NI)	— —
Edgewood	31.4	75, 50, 0 (I)	— —
Edgewood	0	75, 50, 0 (I)	— —
Edgewood	0	75, 0 (NI)	No-till plot

[1]Half of each plot was incorporated (I) and the other half was non-incorporated (NI).

tion rates for chile production in the field have been determined to be 10 to 20 tons per acre. High rates were shown to damage seedlings due to the compost's high salt content. A green waste compost (urea fertilizer plus landscape wastes) was developed in 1996 to address these salt problems and to give growers and gardeners an alternative to the biosolid compost. Neither of the above composts have been evaluated for their abilities to retain moisture in the soil.

The problem of making maximum use of available precipitation for crop production has been addressed by Wofford and Orzolek (1993). Vegetables were successfully produced under dryland conditions with relatively limited rainfall (8 to 25 inches) using a polymer/polypropylene mulch dryland water-catchment system. The system involved incorporating a cross-linked polyacrylamide polymer into the soil, covering the soil with a woven polypropylene mulch, and using transplant vegetables. The woven mulch allowed rainfall to penetrate and retarded water evaporation from the soil.

Pryor (1988) has found that cross-linked polyacrylamide polymer crystals can absorb as much as 400 times their weight in water. When mixed with the soil, the polymer acts like a water reservoir. The crystals are able to return 95 percent of the water to growing plants.

Row covers in combination with plastic mulch also have been found to reduce water use in head lettuce (Anderson and Wheatley, 1994). Reduced water use was attributed to reduced moisture evaporation from the soil, due to the mulch and one less irrigation since the crop matured earlier under the row cover. Although row covers may reduce water use in crops, their primary function is to modify temperature (Wells, 1998). Row covers also help protect against frost, reduce hail damage, provide wind protection, warm the soil, and in some cases, control insects, diseases, and predators.

LIMITED IRRIGATION TRIALS IN NEW MEXICO

A three-year, limited irrigation project was initiated in fall 1996 in New Mexico to evaluate the integrated effects of cross-linked polyacrylamide polymer, polypropylene mulch (black, woven), green waste compost, spunbonded polypropylene row covers, and plastic transplant tubes on the production of various vegetables under limited irrigation. On-farm demonstrations and research trials were conducted at various locations throughout New Mexico. Data were collected on plant mortality, plant growth, yields, water use, weed growth, and mulch durability.

1997 TRIALS

Methods

On-farm trials were conducted at eight locations in New Mexico in 1997 (table 1). Each demonstration project (30 X 50 ft) was divided into four (15 X 25 ft) treatment plots (except Edgewood):

1. Soil only
2. Soil + compost
3. Soil + polymer
4. Soil + compost + polymer

The compost treatments (screened green waste compost) were incorporated in fall 1996 (or early 1997). Soil samples were taken for analysis in the spring from each plot (except Zuni and Portales). Soil moisture content for each plot was evaluated with a LIC moisture meter.

Half of each plot for each polymer-treatment (0, 50 and 75 lbs/1000 ft^2) was incorporated (3-4 inches deep) and half was left on the soil surface. The entire experimental area was covered with two pieces (15 X 50 ft) of woven, black polypropylene plastic mulch (with ultraviolet light inhibitor), overlapped in the middle (6 inches), and secured with 6- and 10-inch fabric pins (3 feet apart). Outside edges were covered with soil.

Transplants were grown in a potting soil mix in 3-inch split plastic tubes in a sunroom. Grower transplants (soil mixes varied) were compared to tube transplants at Edgewood and Portales. A 6-inch fabric pin was inserted through the plastic mulch in front of each hole for transplants to stabilize the plastic. The hole in the mulch was made with a sharpened tire iron for the tubes and with a knife for grower transplants (pots were removed). Crops and varieties varied with location. Each row of transplants in each treatment plot received 25 gallons of water (included starter fertilizer) after transplanting. Exact amounts of water and fertilizer varied at some locations. Thereafter, plots received only natural rainfall.

At Taos and Lyden, alternating rows of chile were covered with spunbonded polypropylene row cover. The row cover was supported by wire hoops and anchored to the mulch with 6-inch fabric pins. Check rows were left uncovered.

Results

When using the LIC moisture meter before incorporating the polymer at planting, five of the seven sites showed more soil moisture in the compost plots than the non-compost plots (table 2). At Arroyo Seco, the soil moisture level measured in the plots treated with compost may have been slightly lower than the untreated plots due to the limited amount of compost applied (table 1). At Roswell, the similarities between treatments may have been due to the heavy soil. Adding compost to the soils at each site (excluding Zuni and Portales) tended to increase pH (66.7 percent of sites), electrical conductivity (83.3 percent), organic matter (100 percent), nitrate nitrogen (83.3 percent), phosphorous (83.3 percent), potassium (100.0 percent) and magnesium (66.7 percent). Calcium and sodium contents were relatively unaffected. In the compost plots, some stunting of the plants was noted early in the season and may have been due to higher salt content in the soil (higher electrical conductivity). The compost also may not have been allowed to cure significantly. This could have resulted in unstable by-products that could have damaged the plant roots.

Table 2. Effects of compost on water retention in various soils (seven sites) across New Mexico, 1997.

Location	Soil Type	Soil Moisture[2] LIC Meter Compost	No compost
Arroyo Seco	Sandy Clay Loam	9.6	10.0+
Roswell	Silty Clay/Loam	7.8	7.9
Garfield	Silt Loam	9.0+[1]	8.4
Portales	Sandy Loam	7.1+	6.8
Aztec	Sandy Clay Loam	3.6+	3.0
Fairview	Sandy Loam	9.1+	8.1
Edgewood	Silty Clay/Loam	10.0+	8.7
Total "+"		(5+)	(2+)

[1]Numbers with "+" indicate a higher moisture content than the alternative treatment.

[2]1 = dry, 10 = field saturation (wet)

The effects of incorporating or not incorporating the polymer were evaluated at five sites. Incorporating the polymer tended to result in larger plants. Leaving the gel on top of the soil may have caused the roots to stay on top of the soil, which could have caused the roots to dry out or overheat during hot weather.

Height and diameter measurements were made on all crops early in the season. On average, the compost/polymer treatment resulted in the largest plants followed by the polymer treatment. The compost treatment was only slightly better than the check. Yield data collected later in the season at most sites, however, indicated the best overall treatment was the polymer. The compost/polymer treatment was only slightly better than the check. The compost treatment gave the poorest results. Again, the compost treatments may have reduced yields due to salts or because the compost had not been allowed to cure sufficiently.

Using grower transplants at Portales resulted in 14 percent less plant (chile) mortality than tube-cultured transplants (45.6 percent). Grower transplant (bell peppers) mortality at Edgewood varied from 15.3 to 34.7 percent, while tube-cultured transplant mortality varied from 63.9 to 75 percent. Plant mortality at Edgewood was mostly due to hail and wind. Similar high plant moralities for the tube-cultured plants were noted at other locations where wind and hail were problems. The sharp edges of the plastic tubes seemed to damage the plants in severe weather. A larger tube might help provide better protection.

At Edgewood and Portales, the tube-cultured transplants had two advantages over the grower transplants. Tube transplants could be planted twice as fast as grower transplants. There were fewer weed problems for the tube-culture technique, since there was no room

Table 3. Amount of irrigation water applied, rainfall and estimated water savings at eight limited irrigation demonstration sites in New Mexico, 1997.

	Acre Inches			[1]Estimated
Location	Irrigation	Rainfall	Total	Water Savings (%)
Arroyo Seco	0.74	2.42	3.16	91.2
Roswell	0.74	10.60	11.34	68.5
Garfield	2.22	4.55	6.77	81.2
Zuni	0.74	10.85	11.59	67.8
Portales	1.48	9.08	10.56	70.7
Aztec	1.48	5.55	7.03	80.5
Fairview	0.74	9.95	10.69	70.3
Edgewood	0.74	12.68	13.42	62.7

[1]Based on 3 acre feet of water (furrow) applied to most vegetable crops in a normal growing season.

for weeds to come up around the tubes. In Edgewood, bindweed emerged around the tube-cultured transplants 5.6 percent of the time, while bindweed around the grower transplants was 27.1 percent.

The polypropylene mulch reduced weed growth at all locations by almost 100 percent. At a few sites, a few weeds emerged around some pin holes. However, weeds (especially kochia and bindweed), were a big problem around the edges of the mulch. Left uncontrolled, they severely reduced plant growth of all crops planted in the outside rows. The width of the two sheets of polypropylene mulch presented problems in the spring wind. Two plots had to be restaked and buckling damaged many of the transplants.

Row covers increased seedling plant mortality (compared with the non-row cover plots) by more than 100 percent at Arroyo Seco and by 51.3 percent at Lyden. Plant mortality was attributed to "damping off" (*Rhizoctonia* sp.). High moisture content under the row cover, legginess of the transplants, and cooler growing conditions in the field probably contributed to conditions favorable for the disease.

Irrigation water (flood) applied at each site varied from 0.74 to 2.22 acre-inches of water (table 3). Rainfall varied from being very dry at Arroyo Seco (2.42 inches) and Garfield (4.55 inches) to relatively high at Edgewood (12.68 inches). Water savings were based on 3 acre-feet of water normally applied to most vegetable crops under furrow irrigation. Savings were impressive, varying from 62.7 percent at Edgewood to 91.2 percent at Arroyo Seco. Although there were significant water savings, supplemental irrigation during periods of stress would have been helpful and probably would have improved fruit quality and yields.

Some crops suffered from water stress, particularly at Portales (sandy soils). Plant growth was good, but peppers were small and infested with blossom end rot. In Roswell, tomatoes were heavily cracked early in the season, but they improved later when there was more rain. In Aztec, cucumbers became bitter and were sunburned. As a result, although yields were good under dryland conditions at most locations, supplemental irrigation would probably have resulted in greater yields and quality.

1998 TRIALS

Methods

Two, replicated, limited-irrigation trials were established at Edgewood and Las Palomas. One to two rates (30 and 50 lb/1,000 ft^2) of polymer were incorporated at both sites and covered with black polypropylene plastic mulch. Other treatments included the mulch (no polymer) and a check (no polymer or mulch). Bell peppers were planted at Edgewood, while tomatoes, cantaloupe and watermelons were planted at Las Palomas.

The plot established at Edgewood in 1997 was reworked and planted to pumpkins. Transplants were used at all locations. Plots received natural rainfall and limited irrigation.

Results

The check plot at Edgewood resulted in the greatest plant mortality (table 4), smaller plants, and lowest yields (table 5). Applying of polymer resulted in generally larger plants and greater yields, although the only significant difference (P(.05) in yield was for the check.

Table 4. Effects of cross-linked polyacrylamide polymer and polypropylene mulch on mortality of 'Aladdin´ bell peppers, Edgewood, New Mexico, 1998.

	Polymer	% Mortality					
Treatment	**lbs/1000 ft²**	**6/16**	**6/23**	**7/1**	**7/13**	**7/27**	**8/10**
Check	0	63.9	71.5	77.8	79.1	80.5	80.5
Mulch	0	2.1	1.4	2.8	3.5	2.8	2.8
Mulch + Polymer	30	0	0	1.4	1.4	2.1	2.1
Mulch + Polymer	50	0.7	0.7	0	0	0	0

Table 5. Effects of cross-linked polyacrylamide polymer and polypropylene mulch on yields of 'Aladdin´ bell peppers, Edgewood, New Mexico, 1998.

	Polymer	Yield (lbs/1000 ft)²		
Treatment	**lbs/1000 ft²**	**Outside Row**	**Inside Row**	**Average**
Check	0	64.8	49.1	56.9a[1]
Mulch	0	494.8	330.4	412.6b
Mulch + Polymer	30	563.8	414.4	489.1b
Mulch + Polymer	50	556.1	375.0	465.5b
Average		419.9	292.0	356.0

[1]Means followed by the same letter are not significantly (P(.05) different, Duncan's multiple range test.

Table 6. Effects of cross-linked polyacrylamide polymer and polypropylene mulch on yields of various vegetables, Las Palomas, New Mexico, 1998.

	Yield (lb/1000 ft)²		
Treatment	**Tomato**	**Watermelon**	**Cantaloupe**
Mulch + Polymer	3223.6a[1]	4931.4b[1]	4072.2c[1]
Mulch	2604.1a	5836.9b	3329.6c
Check	2306.9a	3418.9b	2690.6c

[1]Means followed by the same letter are not significantly (P(.05) different, Duncan's multiple range test.

Table 7. Effects of cross-linked polyacrylamide polymer, green waste compost, and polypropylene mulch on yields of 'Jackpot´ (transplants) pumpkins, Edgewood, New Mexico, Oct. 8, 1998.

Plot	**Polymer**	**Yield**		**Ave. fruit**
Treatment	**lbs/1,000 ft²**	**lbs/1,000 ft²**	**# fruit/1,000 ft²**	**wt. (lb)**
Check/No Mulch	0	432.2	22.2	19.5
Check/Mulch	0	1211.7	77.8	15.6
Polymer/Mulch	50	1526.7	88.9	17.2
Polymer/Mulch	75	1467.2	77.8	18.9
Average		1401.9	81.5	17.2
Compost/Mulch	0	1905.0	88.9	21.4
Compost/Polymer/Mulch	50	1883.0	77.8	24.2
Compost/Polymer/Mulch	75	1802.8	111.1	16.2
Average		1863.7	92.6	20.1

There were no significant differences (P(.05) occurring in yields for any of the treatments at Las Palomas (table 6), although there were trends in favor of the mulch and polymer treatment. There was much variability between plots, probably due to plants dying later in the season. Some plant roots also were heavily damaged by rootknot nematodes.

In Edgewood, the residual effects of the compost plots established in 1997 resulted in larger pumpkin plants and greater yields (table 7). The greatest increase in both growth and yields were due to the compost/ mulch treatment. The lowest yields were in the check plots. The polymer's effects were mixed.

The mulch reduced the time needed to weed (bindweed) the pepper plants at Edgewood by 81.4 percent. The mulch also controlled most of the nutsedge and Bermuda grass at Las Palomas. The wear and tear on the mulch seemed to occur mostly around the planting holes and the pins, resulting in fraying. A propane torch used to make planting holes in the mulch for the pumpkins kept the mulch from fraying. Effects of weather on the mulch were slight. Wind was only a minor problem since most of the plots were only 15 feet wide. Water savings at Edgewood was 68.4 percent (11.37 acre-inches of water for growing season).

1999 TRIALS

Methods

Two replicated trials were conducted at Edgewood (previous 1998 pepper plots were reworked) and at the Agricultural Science Center at Los Lunas. The treatments at Los Lunas consisted of the mulch plus polymer (50 lbs/1,000 ft^2), mulch only, and check (no mulch or polymer). The plots at Los Lunas were planted to two varieties of butternut squash (two rows planted 7.5 feet apart). One row of transplants was covered with spunbonded polypropylene row cover (hoops for support) and the other was left uncovered. The plots at Edgewood were planted to four rows (3 feet apart) of butternut squash (one variety) with 2 feet between plants. One outside row in all treatment plots was covered with the row cover.

One demonstration plot was established at Las Palomas using plots established in 1998 (one replication). Plots were planted to two tomato varieties and two bell pepper varieties. One row of each variety in each treatment was covered with row cover. The other row was left uncovered.

The transplants at all locations were grown in a mix of four parts potting soil mix and one part biosolid compost. Transplants were started in a greenhouse. All plots received natural rainfall and limited irrigation.

Results

Plants in the uncovered plots at Los Lunas were killed twice by frost (April 15 and May 4, 1999) and had to be replanted. Plants in the row cover plots were relatively unaffected. The mulch, polymer/row cover treatment resulted in the greatest increase (compared with check) in growth followed by the mulch/row cover treatment (table 8). This also was reflected in yields (table 9).

Yields in all plots were severely reduced (by as much as a third) due to flooding, resulting in a lot of culls. Although the plots only received 16.08 acre-inches of water (water savings of 55.3 percent based on three acre-feet), heavy rainfall in early August and poor drainage left fruit standing in water resulting in the culls (soft rot).

Early butternut squash production (July 22, 1999) resulted in higher prices on the Growers' Market (75 cents/pound versus 35 cents/pound in September). The mulch was in relatively good shape by the summer's end (two growing seasons). No weeding was required in the mulched plots.

At Edgewood, there was a marked increase in plant growth under the row cover compared with those not under the row cover on June 30, 1999 (table 10). There were little differences between the polymer treatments and the mulch treatment without the polymer. All three mulch treatments, however, showed greater growth than the check. Yields seemed to decrease with greater applications of polymer (table 11). The mulch treatments (even with polymer) outproduced the check plot. Cull production was lower than at Los Lunas. Culls were attributed to cracked fruit that were sold at a lower price on the Growers' Market. Overall, yields were greater than at Los Lunas due to greater plant populations and better weather.

A total of 13.17 acre-inches of water was applied to the plots (including rainfall) for a water savings of 63.4 percent (based on three acre-feet). The mulch (third year of production) was in relatively good shape. No weed control was required for the mulched plots.

Similar results occurred at Las Palomas. The greatest yields (bell peppers) were produced in the mulch/row cover plots. The polymer was relatively ineffective. Most of the tomatoes died of curly top. The row cover was very effective in protecting the plots from frost in the spring. None of the plants under the row covers at any locations died from damping off. This was probably due to the biosolid compost used in the potting soil for the transplants.

Table 8. Effects of mulch, polymer, and row cover on plant growth (diameter) of two butternut winter squash, June 23, 1999, Los Lunas, NM.

	Waltham Butternut Diameter (in.)		Early Butternut Diameter (in.)	
Treatment	**Row cover**	**No row cover**	**Row cover**	**No row cover**
Check	26.3	21.4	23.2	15.1
Mulch	74.5	26.3	60.2	21.0
Mulch + Polymer	99.0	23.3[1]	74.2	17.6[1]

[1]Plants were stunted in first replication due to a heavy ragweed infestation.

Table 9. Effects of mulch, polymer, and row covers on total yields (marketable fruit) of two butternut winter squash varieties of, Los Lunas, NM, 1999.

	Waltham Butternut				Early Butternut			
	Row cover		No row cover		Row cover		No row cover	
Treatment	lb/plot[1]	# ft[3]	lb/plot[1]	# ft[3]	lb/plot[1]	# ft[3]	lb/plot[1]	#ft[3]
Check	3.1	1.7	4.6	4.0	4.1	2.3	6.6	2.0
Mulch	29.6	10.3	10.9	2.7	29.3	11.6	7.9	4.0
Mulch + Polymer	41.4	13.0	6.8[2]	3.0[2]	39.3	15.3	3.6[2]	1.7[2]

[1]Plot = 60 ft^2

[2]Yields were reduced in first replication due to a heavy ragweed infestation early in growing season.

[3]Number of fruit

Table 10. Effects of mulch, polymer and row cover on growth of butternut winter squash growth, Edgewood, New Mexico, June 30, 1999.

	Polymer	**Height (inches)**		**Diameter (inches)**	
Treatment	**(lb/1000 ft^2)**	**Row cover**	**No row cover**	**Row cover**	**No row cover**
Check	0	10.1	6.4	42.9	19.0
Mulch	0	12.8	8.9	69.1	33.6
Mulch	30	13.8	8.9	66.5	32.2
Mulch	50	13.8	8.9	67.1	37.0

Table 11. Effects of mulch, polymer, and row cover on total yields of butternut winter squash yields, Edgewood, New Mexico, 1999.

		Row Cover		**No Row Cover**	
	Polymer	**MKT FT.**		**MKT FT.**	
Treatment	**(lb/1,000 ft^2)**	**Wt. (lb)[2]**	**# ft[3]**	**Wt. (lb)[2]**	**# ft[3]**
Check	0	75.9	20.0	21.7	6.1
Mulch	0	116.1	28.0	34.0	8.9
Mulch	30	105.6	24.1	36.4	8.5
Mulch	50	83.3	18.4	35.1	8.9

[1]MKT FT = Marketable fruit

[2]Plot = 60 ft^2

[3]Number of fruit

CONCLUSIONS

Compost

The green waste compost was effective in increasing the initial water content in 71.4 percent of the soils it was applied to in 1996/1997. Compost also increased pH, electrical conductivity, organic matter, and nutrient content (nitrate nitrogen, phosphorous, potassium and magnesium) in most soils. In the first year, stunting and lower yields in composted plots may have been due to the soil's salt content after applying the compost or the result of not letting the compost cure long enough. In the second year, higher yields associated with the compost at Edgewood may have been the result of better stability and residual nutrients associated with its breakdown. In 1999, using biosolid compost in the potting soil mix seemed to reduce the incidence of damping off in seedlings.

Polymer

The cross-linked polyacrylamide polymer seemed to be most effective on increasing growth and yields the first year it was applied and incorporated, particularly on sandy soils. Thereafter, yields either decreased or were similar to the checks. There is some research[1] that indicates salts in the soil will tend to deactivate the polymer over time.

Mulch

Using black polypropylene mulch (woven) with an ultraviolet light inhibitor had the greatest effect on water savings in this project. With or without the polymer, water savings varied from 55 to 91 percent based on a norm of three acre-feet of water to produce most crops. In addition, larger plants and greater yields in the mulch plots were probably due to soil warming and less weed competition. Weeding was almost eliminated, except along the edges of the plastic. Weeds left uncontrolled along the edges of the plastic reduced crop yields significantly in adjacent rows.

Over a three-year period, the mulch held up well under weathering, eliminating the problem of disposing of it after the growing season. The extra cost of the mulch can be distributed over a number of years. The fabric pins also were reusable, although they were somewhat troublesome to remove each year and tended to rust (10-inch pins were galvanized steel and did not rust). The width of the mulch should be no more than 15 feet (one sheet wide) to reduce problems with wind. Commercial growers may prefer narrower widths. The mulch tended to fray or unravel when cut. Burning holes through the mulch with a propane torch or round branding iron for transplants eliminates this problem.

Transplants

Use of the 1/2-inch diameter split plastic transplant tubes tended to increase transplant mortality due to blowing wind. The transplants also tended to be leggy. The transplanting technique (use of sharpened tire iron) was twice as fast as using traditional transplants. Evaluation of a larger tube might solve some of these problems.

Row Cover

The spunbonded polypropylene row cover was extremely effective in protecting plants from frost, wind, and hail. It also increased early growth and production of most crops. It did, however, tend to repel rainfall, causing it to run down the sides of the row cover. Early harvests of crops like tomatoes were heavily infested with curly top. This was probably due to beet leaf hoppers entering the row cover through holes made by stakes or at the soil surface. Sealing the row cover with soil at the surface and eliminating stakes that rub could prevent this. Properly supported, the row cover could probably be reused for several years.

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Printed November 2000 **Las Cruces, NM**
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