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Research findings submitted to the Organic Farming Research Foundation:

Project Title:

Development of weed control methods and irrigation requirements for organic medicinal herb production in New Mexico, 2003-2004

FINAL PROJECT REPORT

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Summary: We conducted an experiment on certified organic land at the NMSU Sustainable Agriculture Science Center in Alcalde, NM, during the 2003 and 2004 growing seasons to: 1) compare the feasibility and cost effectiveness of drip irrigation to flood irrigation; 2) compare hand weeding to woven plastic weed barrier fabric; and 3) compare yields at low (once weekly) and normal (twice weekly) irrigation levels for three selected native medicinal herbs: oshá (*Ligusticum porteri*), yerba del manso (also known as manso and yerba mansa) (*Anemopsis californica*), and cota (*Thelesperma gracile* or *T. megapotamicum*)

Oshá, a montane species, did not survive in our plots at the elevation of the Alcalde experiment station (5700 feet). Cota established, grew, and yielded well in the hand-weeded plots, but was suppressed in plots with plastic fabric. Cota was able to produce two cuttings of above-ground plant material per season. Cota leaf and stem Dry Matter Weight (DMW) yields in the second season of growth were higher under most low-level irrigation regimes. Hand-weeded, low-level drip irrigated cota treatments were most cost effective, giving costs per pound of dried cota at $3.17.

All manso plants survived and grew well, regardless of treatment. Similarly to cota, manso root DMW yields gathered from the first season of growth were significantly higher in the hand-weeded and drip-irrigated treatments. Establishment-year manso dry root yields were higher under all low-level irrigation regimes, with the exception of the normal-level, flood-irrigated, fabric-mulched treatment. Hand-weeded, low-level drip irrigated manso treatments were most cost effective, giving costs at $14.17 per pound of dried manso root. Cost estimates of each treatment were developed for manso yields after one season's growth and for cota yields after two seasons' growth.

Keywords: medicinal herbs, native species, organic production, irrigation, weed control, cost estimates, *Anemopsis californica, Ligusticum porteri, Thelesperma gracile (T. megapotamicum).*

Introduction: Small-scale and family-oriented organic growers must be continually innovative and efficient in their operations in order to remain in business. One strategy for small and organic farmers is development of niche markets and specialty or high-value alternative crops, such as medicinal herbs.

The American Southwest has a large number of native medicinal herb species that have been used traditionally by indigenous and Hispanic cultures. By and large, these species have been wild-harvested from native stands, mostly for personal, family, or local use. Some of them appear to be adaptable to cultivation, and have the potential of becoming "new" alternative crops. Three in particular, oshá (*Ligusticum porteri*), cota (*Thelesperma gracile* syn. *T. megapotamicum*), and yerba del manso (*Anemopsis californica*), show promise for organic growers in New Mexico and elsewhere in the Four Corners region of the United States.

Oshá (*Ligusticum porteri* Coult. & Rose), in the family Apiaceae, is also known as Porter's lovage or bear root. It is native to North America, and is found primarily in the Rocky Mountain States from Montana to New Mexico, and less frequently in high mountain regions of northern Mexico. Oshá prefers higher elevations, from 7000 to 10,000 feet. It is a slow-growing perennial herbaceous plant, and because the root is the part used, must be destroyed when harvested. The dried root traditionally has been used internally for colds, flu, bronchial congestion, and as a purifying tonic in the spring. Externally, the juice of the fresh root, or a poultice made from the dried root was applied to wounds as an antiseptic.

New Mexico state biologist Robert Sivinski reports that oshá populations have been in a state of decline for the last fifteen years (Robert Sivinski, personal communication, 2003). Oshá is included on the United Plant Savers' "At Risk" list (United Plant Savers website, 2004).

Robbins (1999) classified populations as in decline over the past ten years. Others are in agreement, especially with regard to local populations that can be wiped out by one or more collectors in a given area. In addition to pressures on this species by wild-harvesting, there may be local population decline as a result of habitat destruction for residential and commercial development on private forest lands (MPWG website, 1999). Because of the possibility of localized stand declines, it is important to begin to study ways to cultivate this valuable medicinal herb.

Yerba del manso (*Anemopsis californica* [Nutt.] Hook. & Arn.) in the family Saururaceae, is valued as a traditional cold and flu remedy. Depending on the locale, it is also called yerba mansa, manso, lizardtail, swamp-root, or shrimp-root. In northern New Mexico it is commonly referred to as manso. It is a mesophyte native to wetlands and riparian areas of Southwestern United States and northern Mexico. Manso is a low-growing plant that spreads profusely by rhizomes and stolons, which radiate outward from a central rosette, giving a tail-like appearance, hence the English name "lizardtail", as well as the Latin taxonomic family name, Saururaceae. It has antiseptic, antibiotic, and antiviral properties, and can be used externally on wounds and open sores, or the leaves or roots taken internally as a tea. It acts on mucus-membrane linings, hence its wide range of application in treating sinus problems, gum and mouth sores, canker sores, ulcers, upset stomach, digestive problems, and hemorrhoids.

The United Plant Savers places *Anemopsis californica* on a list of plants "to watch" as a potentially threatened species. In New Mexico, urbanization and habitat destruction, more than over-harvesting, are responsible for stand losses.

Cota, or Navajo Tea (*Thelesperma gracile or T. megapotamicum*) in the family Asteraceae, has considerable commercial potential due to its multiple use as a medicinal, a refreshing beverage tea, and as a dye plant. It has a wide growing range in the western United States, but is most popularly used in the American Southwest. It is typically found in arroyos, washes, sandy dry beds and rangelands where alluvial deposits have formed. It is reputedly beneficial for the kidneys, and is used in folk medicine as a blood purifier. It is very popular as a dye plant, its flowers yielding a golden yellow color used traditionally in local textile and weaving crafts. Although it is a common plant in the Southwest, rising labor and fuel costs make large-scale collecting from the wild for commercial markets uneconomical.

Little is known about production parameters for these species, especially under organic conditions. Raised bed culture that permits intensive growing of crops at higher densities with equidistant spacing is becoming increasingly popular among small-scale growers who need to make the most of limited acreages. We therefore chose this method over single rows for growing oshá, manso and cota.

Weed control is an important consideration for all organic growers, regardless of crop. In the case of these three particular crops, mechanical cultivation with tractor-drawn implements is not an option since oshá and manso are root crops that would be damaged by mechanical cultivators, and cota has brittle stems that could be easily broken by passing implement frames and toolbars. Based on previous research conducted here at the Alcalde experiment station, successful weed control in cucumbers, summer squash, and winter squash has been obtained using woven plastic fabric landscape cloth (George Dickerson, unpublished data, 2002). We decided to compare the cost effectiveness of this method to that of hand weeding the three selected species. Because water is becoming an increasingly scarce and valuable commodity in New Mexico and the rest of the Southwest, determining water requirements for each of these species is of paramount importance, as is choosing the most efficient and economical means of irrigation. Two final factors were included in the experiment, a comparison of drip irrigation to flood or surface irrigation delivery systems, at two irrigation levels, a normal or control rate of approximately twice weekly, and half that rate at approximately once weekly, based on soil moisture resistance readings.

Materials and Methods: The experimental design was a randomized complete block design (RCBD), three factorial structure with two levels for each factor, applied to each of the three chosen species (3 x 2 x 2 x 2). The factors were weed control method (hand weeding vs. woven plastic fabric), irrigation method (drip vs. flood), and irrigation level (normal vs. low level). The design was replicated three times across the field, forming blocks. Plot layout was computer-generated using Minitab® Release 13 statistical analysis software. Each plot was randomly assigned a species, weed control method, irrigation method, and irrigation level, giving every possible combination of factor levels. The total number of plots was therefore 3 x 2 x 2 x 2 x 3 = 72. The resulting treatments for each species were: a) hand-weeded, low-level drip irrigated; b) hand-weeded, normal-level drip; c) hand-weeded, low-level flood irrigated; d) hand-weeded, normal-level flood; e) plastic-mulched, low-level drip irrigated; f) plastic-mulched, normal-level drip; g) plastic-mulched, low-level flood irrigated; and h) plastic-mulched, normal-level flood. The null hypothesis for each species was therefore $H_o = Y_a = Y_b = Y_c = Y_d = Y_e = Y_f = Y_g = Y_h$, no significant difference between treatment DMW yields. Actual material and labor costs were pro-rated by treatments, and then divided by the average yield of each species for each treatment, giving a cost per pound figure in dollars for all respective treatments.

This experiment began in March of 2003 with field tillage to prepare the soil. The site selected for the trial is part of the organically certified area of the Alcalde experiment station (Certificate # NMOCC #204). The soil is sandy loam. The field had been planted to a cover crop mixture of winter wheat and hairy vetch the previous fall (Figures 1 and 2 on the accompanying image CD). The field was subsoiled to an approximate depth of 24 inches, disked three times, and rototilled three times (Fig. 3-6)). The final rototilling was in the direction of the plot layout and was primarily to aid in bed shaping (Fig.7). Bed formation was done with a lister with eight-inch shovels set 52 inches apart (Fig.8). Listing created raised shoulders on the sides of each bed for the purpose of guiding and holding water on the surface-irrigated plots (Fig.9). On plots receiving drip irrigation, these shoulders were raked off and the bed smoothed and leveled (Fig. 10). Drip irrigation valves were then installed and 8-mil drip tape with one-foot pore spacing was placed on plots designated to receive the drip treatment (Fig.11-12). Two tapes were run along the length of the beds, spaced approximately one foot apart (Fig. 13). This was to insure uniform water coverage across the full width of the bed, and to guarantee adequate irrigation on both sides of the center row, typically the sample row in field trials.

Earthmat™, a three-ounce polypropylene woven fabric designed for moisture retention and weed control, was purchased from the DeWitt Company (http://www.dewittcompany.com/wovengc.html). The fabric is identical to that used in landscaping and comes in various widths. We selected 4-foot wide rolls to cover the full width of the bed and installed the fabric by hand on plots designated to receive that treatment. The plastic was unrolled over the bed to a length of 30 feet, cut, and pinned in place (Fig.14-16). The edges were then intermittently covered with soil for added stability and security from wind (Fig. 17-18). A conventional weed flamer of unknown brand was used to burn holes in the fabric for plant placement (Fig. 19). Three-inch diameter holes were burned into three rows on each bed, spaced one foot apart within and between the rows (Fig. 20-21). An added benefit of the use of the weed flamer was the cauterization of the hole edge, fusing the weave and eliminating fraying of the material. The resulting spatial arrangement was an equidistant square pattern with 1-foot by 1-foot spacing on the top of each bed (Fig. 22).

Ten-inch diameter Polypipe™, flexible polyethylene irrigation tubing purchased from Tyco Manufacturing, was installed along the head of each plot (Fig. 23-25). The tubing was attached to a cast aluminum bell housing connected by a riser to the underground piping system fed by the acequia, or irrigation ditch (Fig. 26). Sliding gate valves were inserted into the Polypipe™ corresponding to each plot to be surface-irrigated (Fig. 27-28). These installation activities were conducted over approximately a three-week period.

All plots were pre-irrigated prior to transplanting (Fig. 29-30). Plant collection and transplanting began in early April, beginning with manso. Arrangements were made with neighboring San Juan Pueblo to collect from native stands on their land. On April 10-11, 2003, dormant crowns were dug, washed, blot dried, individually weighed and transplanted to the field (Fig. 31-34). This took most of two days.

Our plans to plant cota from bedding transplants grown from seed were changed after germination and emergence failure. Instead, cota crowns were collected from native stands on private property, with permission from the owner (Fig. 35). Since cota exhibits some phenotypic variability that may be due to genetics, we collected from a single stand only. We had to wait until the crowns had broken dormancy in late April and begun to emerge in order to identify and locate the plants (Fig. 36). Plants were dug in the morning of April 22, 2003, and transplanted to plots the same day.

Oshá dormant crowns were dug from the Canjilón Lakes area of the Carson National Forest in northern New Mexico, after securing permission from the Forest Service Ranger there (Fig. 37-38). Soil from the roots was saved to add to the transplant hole for mycorrhizal inoculation. Oshá root balls were dug, separated into individual crowns, washed, blot dried, weighed, and transplanted into the field (Fig. 39). The entire collection and planting process took three days.

Once planting was complete, all plots were irrigated and weeded regularly to reduce competition and minimize transplant shock. The two irrigation levels were begun after all species had emerged (Fig. 40-42). Irrigation levels were determined by soil moisture monitoring using Watermark™ ceramic block electrical resistance sensors buried to a depth of six inches. Sensors were placed in each block and monitored daily (Fig. 43). The resistance scale in units of centibars ranges from 0 for saturation to 199 for fully dry ceramic blocks. We chose a centibar threshold of 15 for the control plots during the establishment year, based on experience using the blocks with other fruit and vegetable crops. Normal or "control" irrigation treatments were irrigated at this threshold; low irrigation treatments were watered at every other date that the threshold level was reached in the control plots. Under this procedure, centibar readings in the low irrigation treatment plots ranged from 20 to 25 on the day of irrigation. During the summer weeks, thresholds were reached in the control plots on the order of every 3-4 days. This resulted in a typical irrigation schedule of about twice a week, and about once a week for the low-level treatments. Water flow rates were determined for both drip and surface-irrigated systems, and irrigation duration was calibrated to match total water volume for both systems as closely as possible. See the attached calculations in the appendix for these figures.

All plots were weeded as needed. A minimal amount of hand pulling of bindweed was needed around some of the holes of the plastic-covered treatments, but the majority of hand weeding was done on the uncovered plots. All weeding on the bed tops was done by hand pulling to avoid possible nicking of drip tapes, and to avoid cutting of basal growth around cota and manso plants (Fig. 44). Bed shoulders and furrows between beds were hoed. Weeding labor was calculated from the time of entering the field until completion of the weeding operation, and then pro-rated across the hand-weeded treatments to give per-plot weeding time averages. Weed presence was uniform across the field, and time spent removing bindweed from the plastic-covered treatments was negligible (Fig. 45).

Cota was harvested twice during each of the two seasons. In the establishment year of 2003, harvests were made on July 17th and September 02. In 2004 harvests were made on June 30th and August 26th. In each case, harvest time was determined by peak bloom of the majority of flower buds (Fig. 46). All above-ground plant material of each plot was removed with hand sickles to an approximate height of 3 inches from the soil surface and weighed fresh in the field. Fresh weights of subsamples were then taken and the samples dried in a precision oven at 65^{o} C (140^{o} F) for 48 hours. Each sub-sample was then re-weighed to obtain dry weight and moisture content. Because 2003 was the year of establishment, only 2004 yields were considered in the cota yield analysis.

Manso roots were harvested in 2003 after complete senescence and desiccation of the top growth (Fig. 47). Normally this would occur in early October after killing frosts, but unusually mild temperatures in the fall of 2003 delayed harvest until November 11th. Five plants from the center row were selected from the front quarter of each plot, leaving the remaining plants for future sampling (Fig. 48). As much of the root ball as possible was removed from a diameter of approximately 18 inches away from the base of the plant, and to a depth of approximately 12 inches (Fig. 49). Soil and above-ground material was removed, leaving as much of the root mass intact as possible (Fig. 50-53). Roots were carefully and thoroughly washed, then dried in a precision oven at 65^{o} C (140^{o} F) for 48 hours, and subsequently weighed. Second-year yield data for manso were not available at the time of this writing, so establishment-year (2003) sample data were used for analysis.

Results and Discussion: A) Yields -- Cota and manso yield data are presented in tables in the appendix.

1) Cota -- Above-ground DMW cota yields are presented in Table 1. An analysis of variance (ANOVA) test was performed using Minitab Release 13 for Windows® on cumulative 2004 cota DMW yields and two additional response variables, crown survival and side shoot numbers, measured in 2003 (Table 2 and Table 3). Significant differences were found for all three variables only between weeding methods. DMW yields were significantly greater in hand-weeded treatments, regardless of irrigation method or water amount. We speculate that the plastic fabric restricted or inhibited emergence and plant growth at the edges of each cauterized hole opening, though other factors related to the plastic mulch, such as soil temperature, compaction, or decreased aeration cannot be ruled out (Fig. 54-55). Yields were consistently higher in most low irrigation level treatments, indicative of cota's adaptation to drought-prone dryland conditions. We observed some necrosis and dieback in the centers of the high-level irrigation treatments, which may explain the lower yields in those treatments compared to the low-level treatments. Higher water amounts or more frequent irrigations may induce more diseases in dense stands of cota similar to those in our plots.

2) Manso -- Yield data are presented in Table 4 in the appendix. An analysis of variance (ANOVA) was conducted on root dry matter weight (DMW) with tests for interactivity of the predictors weed control method, irrigation method, and irrigation level (Table 5). The resulting ANOVA table indicates manso yields in hand-weeded plots were significantly greater than those under plastic, and yields under drip were significantly greater than flood-irrigated plots. Treatment means between irrigation levels were not significant, and there were no apparent interactions of significance. A means separation test performed on treatment means of combined factors showed only the hand-weeded, low-level drip-irrigated treatment mean (5372 lb/A) was significantly greater than the other yield means. However, one must keep in mind that manso is

a perennial root crop requiring several years to reach a mature root size, and that this data reflects the response of manso to the various treatment factors after only a single season of growth. Therefore, any conclusions drawn from establishment-year results would be premature.

B) Economic Data -- Economic figures for cota and manso are presented separately in accompanying spreadsheet files, and summarized in the appendix as costs per treatment for each crop (Table 6). In the spreadsheet files, costs per treatment and per-pound costs are presented in the top half of each page, while a detailed itemization of material and labor inputs are given below them.

Flood irrigation costs were greater than drip irrigation costs due to labor. Total flood irrigation costs per treatment were $57.92 for low-level treatments, and $69.08 for the control or normal-level treatments. The difference was due to the additional labor required to attend to the extra water application each week. Total drip irrigation costs per treatment were $43.86. Material inputs were greater for drip treatments than flood treatments, but installation labor was greater for flood treatments. Flood irrigation also required additional labor throughout the season each watering to open, adjust, monitor, and turn off individual gates at each plot, as well as attending each plot to watch for breakouts, overflows or other possible problems.

Plastic fabric material and labor costs per treatment came to $50.69. Hand weeding costs were exclusively labor inputs and were $60.55 per treatment.

Total costs per treatment ranged from $94.56 to $129.62. Plastic-mulched, drip-irrigated systems were least expensive, generally due to labor savings. Conversely, hand-weeded, flood-irrigated, normal-level treatments cost the highest, because of higher labor inputs. However, for both cota and manso, the most economical treatment on a per-pound basis was the hand-weeded, drip-irrigated, low-level treatment, due to the increased productivity of both species under those conditions. Cota costs per pound were $3.17 and manso costs per pound were $14.17, respectively. Since manso cost-per-pound figures are for establishment year yields, these costs can be expected to come down to more realistic levels in subsequent years as roots mature and yields increase.

Conclusions: This trial was very useful in pointing out the importance of matching technology to the growth habit of any given crop. Permeable woven landscape fabric has generally been demonstrated in the horticultural and nursery industries to be an effective non-chemical weed control method with minimal negative impact on the desired plants. However, in the case of species like cota, which is rhizomatous, or yerba del manso, which is both rhizomatous and stoloniferous, plastic weed barrier cloth may seriously curtail such growth. Organic growers should take these factors into consideration in choosing weed control options.

Drip irrigation, while having higher up-front material costs and investment, is more water efficient and may not compact or move the soil as much as flood irrigation, which may explain the higher yields of both cota and manso in drip-irrigated treatments in this trial. Even including labor for minor repairs, our drip irrigation system required less labor. On the other hand, Polypipe™ polyethylene irrigation tubing and its use in flood or furrow-irrigated fields may still be more economical to growers who use family labor or do not hire additional field labor. Growers can use the results of this trial as a guide in their selection of irrigation methods, but will need to look at their own financial and labor situation in determining which one will fit best into their operation.

In conclusion, this trial demonstrates the feasibility of cultivating cota and manso as potential alternative crops for organic growers, and establishes a starting point for the production parameters of weed control, irrigation method, and irrigation level for these crops under growing conditions similar to those found at the Alcalde experiment station in north-central New Mexico.

Outreach: On January 24, 2003, a press release announcing the organic herbs study was issued, along with an article at the NMSU College of Agriculture and Home Economics (CAHE) website, "CAHE News Center" (http://spectre.nmsu.edu/media/news2.lasso?i=306). On August 23, 2003, the Alcalde experiment station Field Day was held, with over 200 farmers and community members attending. A stop at the organic herbs research plots was part of the medicinal herbs research tour, and preliminary cota yields were presented as part of the program. On September 16, 2004, a Field Day focusing on medicinal herb research was held at the Alcalde experiment station, with 136 growers and other visitors attending. The experimental plots and updated information were again part of the field tour.

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Appendix

1) Calibration of Irrigation Systems --

a) Surface-irrigated -- Flow rate at each gate averaged 9600 ml/minute (2.54 gallons per minute) across all blocks @ 1/4 inch gate opening x 45 minutes =114 gallons per bed.

b) Drip -- Manufacturer's calibration for T-tape 5/8" 8 mil tape with 12-inch pore space @ 8 psi nominal = .34 gpm per 100 feet of row (from their website http://www.tsystemsinternational.com/NorthAmerica/Products/ProCatalog/TSX500.html) x 40 feet of row (two tapes 20 feet long) = .136 gpm. 114 gallons/. 136 = 14 hours.
Our in-field measurements of pore flow averaged .53 gpm/100 feet of row @ 15 psi, or .21 gpm per bed. 114 gallons/. 21 = 9 hours. We therefore irrigated drip beds 9 hours to match surface-irrigated volume.

Table 1. Cota DMW Yield Means, by Treatment (lb/A)

Weeding	Hand				Plastic			
Irrigation	Drip		Surface		Drip		Surface	
H_2O level	Low	Normal	Low	Normal	Low	Normal	Low	Normal
2003	2,396	1,982	2,396	1,633	762	1,023	936	784
2004	7,986	5,082	7,042	6,171	2,664	1,858	1,386	1,742
Cumulative	10,382	7,064	9,438	7,804	3,426	2,881	2,322	2,526

Table 2. Cota Supplemental Parameter Means, (averages per treatment), 2003

Factor	Hand Weeding	Plastic Mulch
Survival (%)	51	40
Side Shoot Number	36	1

Table 3. Cota Analysis of Variance (ANOVA), with interactions, 2004

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Factor      Type    Levels       Values
Weeding    fixed       2     Hand    Plastic
Irrigati   fixed       2     Drip    Surface
Level      fixed       2     Low     Normal

Analysis of Variance for 04 Totl, using Adjusted SS for Tests

Source                   DF     Seq SS     Adj SS     Adj MS        F       P
Weeding                   1    237.592    237.592    237.592    34.70   0.000
Irrigati                  1      0.551      0.551      0.551     0.08   0.780
Level                     1     10.258     10.258     10.258     1.50   0.239
Weeding*Irrigati          1      0.839      0.839      0.839     0.12   0.731
Weeding*Level             1      9.854      9.854      9.854     1.44   0.248
Irrigati*Level            1      9.346      9.346      9.346     1.36   0.260
Weeding*Irrigati*Level    1      0.170      0.170      0.170     0.02   0.877
Error                    16    109.551    109.551      6.847
Total                    23    378.159
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Table 4. Manso Root DMW Yields, lb/A, 2003

Weeding	**Hand**				**Plastic**			
Irrigation	**Drip**		**Surface**		**Drip**		**Surface**	
H_2O level	**Low**	**Normal**	**Low**	**Normal**	**Low**	**Normal**	**Low**	**Normal**
Yield	5,372	3,862	3,412	3,006	3,811	3,049	2,708	2,977

Table 5. Manso Analysis of Variance (ANOVA) with interactions for Root DMW, 2003

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Factor      Type     Levels         Values
Weeding    fixed       2          Hand    Plastic
Irrigati   fixed       2          Drip    Surface
Level      fixed       2          Low     Normal

Analysis of Variance for Manso Root DMW, using Adjusted SS for Tests

Source                   DF     Seq SS     Adj SS     Adj MS       F       P
Weeding                   1     1074.9     1074.9     1074.9    4.52   0.049
Irrigati                  1     1805.8     1805.8     1805.8    7.60   0.014
Level                     1      657.1      657.1      657.1    2.76   0.116
Weeding*Irrigati          1      299.5      299.5      299.5    1.26   0.278
Weeding*Level             1      221.9      221.9      221.9    0.93   0.348
Irrigati*Level            1      524.7      524.7      524.7    2.21   0.157
Weeding*Irrigati*Level    1        3.0        3.0        3.0    0.01   0.913
Error                    16     3803.3     3803.3      237.7
Total                    23     8390.2
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Table 6. Total treatment costs for all crops and per pound costs for manso and cota

Weeding	**Plastic**				**Hand**			
Irrigation	**Flood**		**Drip**		**Flood**		**Drip**	
H_2O level	**Low**	**Normal**	**Low**	**Normal**	**Low**	**Normal**	**Low**	**Normal**
Drip Costs	0.00	0.00	43.86	43.86	0.00	0.00	43.86	43.86
Flood Costs	57.92	69.08	0.00	0.00	57.92	69.08	0.00	0.00
Plastic Costs	50.70	50.70	50.70	50.70	0.00	0.00	0.00	0.00
Hand Costs	0.00	0.00	0 .00	0.00	60.55	60.55	60.55	60.55
Total Costs	**108.62**	**119.77**	**94.56**	**94.56**	**118.47**	**129.62**	**104.41**	**104.41**
Manso, $ /lb.	29.20	29.57	18.06	22.60	25.52	31.39	14.17	19.83
Cota, $/lb.	19.01	13.52	8.63	12.35	4.09	4.97	3.17	4.97

Project photos from Alcalde Experiment Station, Alcalde, NM

Cota Costs per Treatment of Harvested Crop										
			-----Plastic-----		-----Plastic-----		-----Hand-----		-----Hand-----	
			flood		drip		flood		drip	
Drip			**Low**	**Normal**	**Low**	**Normal**	**Low**	**Normal**	**Low**	**Normal**
Drip Tape Materials					15.18	15.18			15.18	15.18
Installation Labor					23.90	23.90			23.90	23.90
Leak Repair Labor					4.78	4.78			4.78	4.78
Flood										
Materials			8.53	8.53			8.53	8.53		
Installation Labor			38.24	38.24			38.24	38.24		
Irrigation Labor			11.15	22.31			11.15	22.31		
Plastic										
Materials			18.03	18.03	18.03	18.03				
Installation Labor			32.66	32.66	32.66	32.66				
Hand										
Weeding Labor							60.55	60.55	60.55	60.55
TOTAL COSTS THAT VARY BY TREATMENT			**108.62**	**119.77**	**94.56**	**94.56**	**118.47**	**129.62**	**104.41**	**104.41**
Avg. yield (g/plot)			868.50	1,347.00	1,666.10	1,164.00	4,400.70	3,968.20	5,011.40	3,193.00
Yield per treatment (g/3plots)			2,605.50	4,041.00	4,998.30	3,492.00	13,202.00	11,904.60	15,034.20	9,579.00
Yield per treatment (lbs)			5.74	8.90	11.00	7.70	29.10	26.20	33.10	21.10
Cost/gram ($) per treatment			0.04	0.03	0.02	0.03	0.01	0.01	0.01	0.01
Cost per pound per treatment			**19.01**	**13.52**	**8.63**	**12.35**	**4.09**	**4.97**	**3.17**	**4.97**
Input Cost Details										
MATERIALS										
Drip Irrigation	**ft/unit**	**cost/ unit**	**bed length**	**ft of tape/bed**	**cost/ft or unit**	**Units per bed**	**cost per bed**	**Number of Treatments**	**#beds per treatment**	**total cost per treatment**
T-tape	4000	$ 147.00	30	60	$0.04	2	$2.21		3	$ 6.62
Blue Line (manifold)	1000	$ 120.00	30	4	$0.12		$0.48		3	$ 1.44
Connectors		$ 0.30				2			3	$ 1.80
Valves & Fittings		$ 21.30						4		$ 5.33
TOTAL										**$ 15.18**
Flood Irrigation										
PolyPipe	1320	$ 350.00		4	$0.2652		$1.0606		3	$ 3.18
Gates		$ 1.36				1			3	$ 4.08
Bell housing (used)		$ 0.21						12		$ 0.02
Hose clamp		$ 5.00						4		$ 1.25
TOTAL										**$ 8.53**
Plastic mulch										
Barrier Cloth 4'x300'	300	$ 48.00	30	30	$0.16	1	$4.80	3		$ 14.40
Anchor Pins (need pins/ft)	1000	$ 50.00			$0.05	12	$0.60	3		$ 1.80
Weed burner		120								$ 1.00
Propane		$ 10.00								$ 0.83
TOTAL										$ 18.03
LABOR		**Hours**	**Cost/hou**	**total cost**		**Number weeded beds**	**Number cota beds**	**# of treatments**		
Hand Weeding		76.00	$ 9.56	$ 726.56		36	12.00	4		$ 60.55
Normal irrigation labor		14	$ 9.56	$ 133.84		36	12.00	2		$ 22.31
Low irrigation labor		7	$ 9.56	$ 66.92		36	12.00	2		$ 11.15
Mulch installation										
Laying plastic mulch		30	9.56	$ 286.80		36	12.00	4		$ 23.90
Hole burning in plastic mulch		11	9.56	$ 105.16		36	12.00	4		$ 8.76
TOTAL										$ 32.66
Drip installation										
Installation (manifold, t-tape, etc)		24	9.56	$ 229.44		36	12.00	4		$ 19.12
Line flush, check & seal		6	9.56	$ 57.36		36	12.00	4		$ 4.78
TOTAL										$ 23.90
Polypipe installation for flood		48	9.56	$ 458.88		36	12.00	4		$ 38.24
Drip Repairs		6	9.56	$ 57.36		36	12.00	4		$ 4.78

Manso Costs per Treatment of Harvested Crop										
			-----Plastic-----		**-----Plastic-----**		**-----Hand-----**		**-----Hand-----**	
			flood		**drip**		**flood**		**drip**	
Drip			**Low**	**Normal**	**Low**	**Normal**	**Low**	**Normal**	**Low**	**Normal**
Drip Tape Materials					15.18	15.18			15.18	15.18
Installation Labor					23.90	23.90			23.90	23.90
Leak Repair Labor					4.78	4.78			4.78	4.78
Flood										
Materials			8.53	8.53			8.53	8.53		
Installation Labor			38.24	38.24			38.24	38.24		
Irrigation Labor			11.15	22.31			11.15	22.31		
Plastic										
Materials			18.03	18.03	18.03	18.03				
Installation Labor			32.66	32.66	32.66	32.66				
Hand										
Weeding Labor							60.55	60.55	60.55	60.55
TOTAL COSTS THAT VARY BY TREATMENT			**108.62**	**119.77**	**94.56**	**94.56**	**118.47**	**129.62**	**104.41**	**104.41**
Avg. yield per sample (g/5 plants)			47.10	51.30	66.30	53.00	58.80	52.30	93.30	66.70
Yield per treatment (g/180 plants)			1,696.00	1,847.00	2,387.00	1,908.00	2,117.00	1,883.00	3,359.00	2,401.00
Yield per treatment (lbs)			3.73	4.10	5.25	4.20	4.67	4.10	7.40	5.29
Cost/gram ($) per treatment			0.06	0.06	0.04	0.05	0.06	0.07	0.03	0.04
Cost per pound per treatment			**29.20**	**29.57**	**18.06**	**22.60**	**25.52**	**31.39**	**14.17**	**19.83**
Input Cost Details										
MATERIALS										
Drip Irrigation	**ft/unit**	**cost/ unit**	**bed length**	**ft of tape/bed**	**cost/ft or unit**	**Units per bed**	**cost per bed**	**Number of Treatments**	**#beds per treatment**	**total cost per treatment**
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Blue Line (manifold)	1000	$ 120.00	30	4	$0.12		$0.48		3	$ 1.44
Connectors		$ 0.30				2			3	$ 1.80
Valves & Fittings		$ 21.30						4		$ 5.33
TOTAL										**$ 15.18**
Flood Irrigation										
PolyPipe	1320	$ 350.00		4	$0.2652		$1.0606		3	$ 3.18
Gates		$ 1.36				1			3	$ 4.08
Bell housing (used)		$ 0.21						12		$ 0.02
Hose clamp		$ 5.00						4		$ 1.25
TOTAL										**$ 8.53**
Plastic mulch										
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Anchor Pins (need pins/ft)	1000	$ 50.00			$0.05	12	$0.60	3		$ 1.80
Weed burner		120								$ 1.00
Propane		$ 10.00								$ 0.83
TOTAL										$ 18.03
LABOR		**Hours**	**Cost/hour**	**total cost**		**Number weeded beds**	**Number manso beds**	**# of treatments**		
Hand Weeding		76.00	$ 9.56	$ 726.56		36	12.00	4		$ 60.55
Normal irrigation labor		14	$ 9.56	$ 133.84		36	12.00	2		$ 22.31
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