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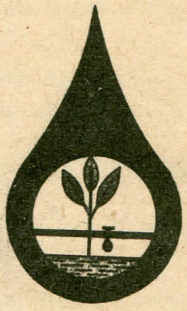

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HISTORY AND PRESENT TRENDS OF DRIP IRRIGATION

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ABSTRACT.The beginning of what is now called drip/trickle irrigation dates back to 1860. Work was carried out in; 1/ Denmark, 2/ England, 3/ France, 4/ Germany, 5/ Holland, 6/ Israel, 7/ Italy, 8/ U.S.A., and 9/ U.S.S.R. Sub-surface irrigation, porous tube, plastic tube in the root zone and above ground hoses with emitters were the various stages in the development of drip/trickle type irrigation. Greenhouse operators and plant growing nurseries, out of necessity, devised the first drip/trickle type irrigation systems to irrigate thousands of potted plants.

In 1969 the author introduced the drip/trickle irrigation philosophy to the U.S.A. after spending a years' sabbatical in Israel. It was during 1968-69 that Dr. Dan Goldberg introduced the author to the work being done on many agricultural crops.

The first installation of drip irrigation on a commercial scale to an agricultural crop was made in Northern San Diego County, in a five acre avocado orchard. The field research was accomplished on the Trendel Bros. orchard, and is commonly referred to as „The Trendel Project."

Ten years have passed since that project was initiated. Since that time drip/trickle has spread throughout the United Stated and to many countries around the world.

INTRODUCTION

In 1974 the author conducted the first drip/trickle irrigation survey of the United States and certain foreign countries. The purpose of the survey was to obtain an over-all view of the development of drip/trickle irrigation. It is now over ten years since drip irrigation was introduced into California to be used on commercial agricultural crops. The initial work began on an experimental five acre avocado orchard in northern San Diego County. Experimentation has spread to many countries of the world and to most of the United States. Large scale plantings, utilizing drip irrigation, of most agricultural crops, have gone in. In July, 1974, the 2nd International Drip /Trickle/ Irrigation Congress was held in San Diego, California. It was the culmination of five years of research, field testing and growers using the new method of irrigation. Twenty-nine countries were represented at the week long meetings, and with delegates from almost all the states of the U.S.A. in attendance. Over 100 technical papers were presented and are contained in the Proceedings of the Congress. Sixty-five manufacturers displayed their products in seventy booths. Opening day for the exhibits drew 2.000 people. One thousand persons registered for the Congress with each scientific session drawing 800-900 growers, scientists, commercial company representatives and educators. The

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1974 Drip Irrigation Congress appeared to be the impetus the fledgling industry needed to become an important part of the large irrigation industry. This report will attempt to trace the development of drip/trickle irrigation in; 1/ California, 2/ United States of America, and 3/ various foreign countries.

DISCUSSION

The history of drip/trickle irrigation may be summarized briefly as follows:

Sub-surface Irrigation	
1860 –	Germany
1913 –	U.S.A. /Colorado/
1920 –	Germany
1923 –	England, France, Holland, U.S.A. and U.S.S.R.
1932 –	France
Porous Tube	
1934 –	U.S.A.
Plastic Tubing /Spaghetti/	
1950 –	Germany, Italy
1962 –	Israel, U.S.A.
1965 –	Denmark, France, Holland, U.S.A.
Drip/Trickle Emitters	
1970 –	England, France, Italy, U.S.A. and others

During the ten years since drip irrigation was introduced into California, there have been many drip/trickle systems installed on commercial agricultural crops. The initial work that was started in the avocado orchard in San Diego County caused the acreage to increase tremendously. During these ten years many growers, manufacturers, irrigation dealers, representatives, researchers and extension personnel have conducted widespread experiments. Many crops are under test with drip irrigation.

Manufacturers of various types of irrigation equipment have come into the field to produce emitters, pressure regulators, fertilizer tanks, fertilizer pumps, and other hardware required in the drip irrigation system.

Irrigation meetings were held by the University of California Extension Service to disseminate information on drip irrigation as field experience and research data became available. Acreage in 1969 was just minimal as far as field grown agricultural crops were concerned. Nurserymen, greenhouse operations and flower growers were utilizing the spaghetti type trickle irrigation.

Drip irrigation caught on in San Diego County among avocado growers because of high cost water, fairly saline water, and hillside plantings. All of these conditions seemed to fit right in with drip irrigation. Most avocado orchards in San Diego County are planted on hillsides. This is for economic reasons as well as for cultural reasons. The avocado is sensitive to frost and, therefore, the higher on the hillsides the trees are planted the more chance they have of natural frost protection. No frost protection equipment is utilized in avocado orchards. Another reason for selecting hillsides is that land is cheaper and the possibility of urban encroachment is less than in the areas where land is flat or relatively flat. Hillsides are cleared of natural brush and orchards planted. There are no longer small acreages going in, such as was the case when the industry was beginning 20 to 30 years ago. Today the smallest is usually 5 to 10 acres but most of them are 30, 50 and even as high as 500 acres when the operation has been syndicated. Two types of irrigation systems are installed in these orchards, the conventional spitter system that can be converted to sprinklers and to the drip system. There are different ways the drip irrigation system is being installed. Some will use conventional buried PVC rigid pipe with a riser to each tree, and a plastic hose with emitters attached to the riser. Another method is to lay the hose on the ground in one continuous line near the trunk of the tree with three of four emitters placed at each tree site.

Growth of the drip irrigation method can be seen by comparing a few figures. In 1970, shortly after the avocado experiment was installed, a drip irrigation seminar was held in Escondido. One year after the introduction of drip irrigation to San Diego, 600 interested people attended the seminar to hear the drip irrigation story. At this meeting, 18 menufacturers of drip irrigation equipment displayed their products. Seminars were held in 1971, 1972, and 1973. The 1973 seminar drew an estimated 1 200 to 1 500 people from all over California and from many states of the U.S.A., as well as foreign countries. Thirty-four manufacturers of drip irrigation equipment had exhibits at the meeting. Because of the tremendous increase in the use of drip irrigation in California and the U.S.A., San Diego was invited to host the Second International Drip Irrigation Congress. In July, 1974, the Second International Drip Irrigation Congress was held in San Diego, with over 2 000 persons attending from 29 countries. There were about 70 exhibitors.

A more complete list of agriculture crops now using drip irrigation is necessary to tell the story of this new method of irrigation. Drip irrigation will not fit every agriculture crop, or every situation, or every grower's personal likes. However, at the present time, there are more crops being tested with this method of irrigation than crops not being tested. Following is a list of the known crops using drip irrigation: avocados, grapes /table and wine/, strawberries, grapefruit, lemons, limes, navel oranges, tangerines, tangelos, macadamia nuts, papaya, peaches, pears, persimmons, walnuts, apples, boysenberries, tomatoes, cucumbers, celery, potatoes, peppers, melons, corn, asparagus, egg plant, peas, lettuce, ornamental trees and shrubs, bedding plants, cactus and succulents, bulbs, carnations, gladioli, poinsettias, avocado nurseries, citrus nurseries, chrysanthemums, ground covers on highway road cuts, street medians, turf /both in the home and golf courses/, Christmas trees, forestry trees, radishes, apricots, pistachio, plums, cherries, almonds,

pecans, sugar cane, pineapple, cotton, sorghum, alfalfa, pasture, wheat, coffee, bananas, mangoes, olives, figs, passion fruit, and many more minor fruit and vegetable plants.

The field research work in California caused great interest for people from other areas of the United States and foreign countries. Visitors from both Government agencies and private industry made trips to San Diego and California to view the work. Many Manufacturers came to observe how drip irrigation can be adapted to commercial agriculture. Key personnel from foreign countries doing research work on drip irrigation visited us. Dr. Dan Goldberg and Dr. Baruch Gornat of Israel, and Fergus Black of Australia, are three of the better known researchers on the international scene. People came from France, Germany, Switzerland, Italy, many countries of Africa, Israel, New Zealand, Australia, Canada, Indonesia, India and Mexico.

Equipment used in drip irrigation systems is very important. There are many pieces of equipment required. They include plastic hose or pipe, spaghetti hose, emitters, pressure regulators, pressure gauges, valves, fertilizer tanks, filters - both sand and screen, time clocks, tensiometers, evaporative pans, meters, and fertilizer injectors.

One of the most important items in the hardware for drip irrigation is the filter. Filtration is a must and many growers now feel that extra money put into filtration will give them the required performance from their emitters. One grower has two of the largest sand filters backed up by two large screen type filters. In a recent check of his orchard, which encompasses approximately 90 acres of avocados, 25 acres of eleven year old trees, 27 acres of seven year old trees, and 35 acres of four year old trees, he found only 11 emitters out of 30 000 not functioning. He attributes the good performance to proper filtration.

Increasing numbers of installations are going in with complete automation. This is either with the use of an automatic timer that can be set for daily operation at a certain hour of the day, or the more sophisticated unit that is controlled by electrified tensiometers under the trees and having an electrical impulse trigger off the system when the soil moisture reaches a certain dryness. For instance, tensiometers are set to go on at 15 centibars. When the soil has dried to this point, the tensiometer sends a signal to the control head, and this in turn registers in the automatic timer so when the scheduled time arrives for the system to go on, it automatically does so because both the automatic timer and the tensiometer tells the system to turn on. The automatic timer is set for operation at 9 o'clock in the evening and again at 4 o'clock in the morning. The 4 o'clock time is in case the two-hour scheduled watering is not sufficient to move the tensiometers below the point where it would automatically shut off the system.

Pressure regulation is very important. The difference of discharge of water from one emitter to the other must be kept to a minimum. On hillside plantings, this becomes extremely important and critical. In designing systems, engineers must be careful to make allowances for difference in elevation, either by pipe size difference or the installation of numberous pressure regulating devices so the same amount

of water comes out of the emitter at the bottom of the orchard as at the top. Also, the fill up time of the system, as well as the drain out time, should be fitted into the calculations so one set of trees does not get more water than another portion of the orchard.

There are many emitters on the market doday. They fall into three main categories; the moving parts type, the adjustable type, and the fixed discharge type. Examples of the three types are as follows: moving parts, Spears, Rebat; adjustable, Salco; and the nonadjustable , Drip-Eze, Netafim, and Vortex.

PROBLEMS

The # 1 problem with an overwhelming response, is the need for filtration. Inoperative emitters due to clogging from dirt, rock, silt, algae, slime, salt and roots were reported on almost every returned questionnaire. Following is a list of problems reported by workers throughout the world.

1. No system to tell when emitters are clogged.
2. Product quality not good
3. Initial cost of system
4. Water quality
5. Manufacturer tolerance controls
6. Polyethylene hose quality poor
7. Rodents /coyote, rabbits, mice, squirrels/
8. Pressure regulation on hillsides
9. High labor to check each emitter
10. Inadequate design - also inadequate installation ability throughout dealer network
11. Monitoring method needed for mineral/nutrient availability or uptake
12. Develop ways to use tubes for more than one year
13. Iron and sulfer deposits
14. Improved management skills needed
15. Availability of material
16. Need for more information
17. Economics of system
18. Leaks in system
19. Adapting drip technique to local conditions
20. Unfamiliarity with system
21. Justifying high cost of system with generally low cost, good quality water
22. Acidity, heavy metals in water
23. In row crops, emitter lines snake down row
24. Operator training
25. Lack of industry standards for equipment
26. Overwatering or underwatering
27. Installation time too great
28. Lack of dependability of some equipment
29. Flow control
30. Thorny spikes of oil palm trees requires buried lines

31. Need for more basic research
32. In some areas, equipment not available

COMMENTS

Many comments concerning the future of drip irrigation were given in the questionnaire. Here are some quotes:

from California

„Excellent, with substantial growth during next five years - especially in conversion. . .

from California /continued/

– Numerous challenges to the drip system still to be resolved . . .
– Water savings, reduced labor, less fertilizer, better production, unlimited use in future . . .

from Delaware

– Interest is high and growing . . .

from Florida

– Drip irrigation is most definitely the answer to growers' irrigation needs . . .
– State is running out of water - drip will be a necessity . . .

from Hawaii

– Drip irrigation is being installed as fast as money and time permits - future looks good

from Nebraska

– A great deal of interest in drip irrigation is expressed, but there are few actual installations . . .

from New Jersey

– At present time we are 99 % sprinkler irrigation. Until water supply becomes critical, I see no rapid move to trickle irrigation. . .

from Mexico

– Because of agrarian laws, most installations are government sponsored . . .

from Puerto Rico

– The system has dramatically improved our mango orchard . . .
– It has promise for fruit trees, especially avocados . . .

from South Africa

– No decline in the demand for drip systems
– More areas are learning of the benefits of drip . . .

from United Kingdom

– Anticipate expansion in outdoor crops. . .

from West Africa /Senegal/

– Very good response comparing drip with other systems. . .
– Saves 30 % of water and fertilizer – big advantage . . . "

CONCLUSIONS

The response from over 100 sources throughout the world where drip irrigation is being used, provides a good up-date on what is happening in the use of this new method of irrigation. Generally speaking, the following conclusions can be drawn:

— In areas of short rainfall, short supply of water and poor quality of water, drip irrigation has caused considerable interest.
— In areas of high rainfall, but occurring during a short period, supplemental irrigation with drip is being used.
— Where water costs are high / S50-135/acre foot/ and where orchards, vineyards and vegetable fields are planted on hillsides, there is great interest in drip irrigation.
— In areas of abundant water of low cost and high quality, there is very little interest in drip irrigation.
— Where terrain is steep, labor expensive and somewhat unavailable and water quality marginal, drip irrigation is being used.
— Drip irrigation is not a panacea – is not for every person, on every crop or on every soil or under every condition.
— Drip irrigation is just another way of irrigation, along with basin, flood, furrow and sprinkler.
— More basic research on drip irrigation should be done.
— The industry should work towards standardization of materials and equipment.
— Better management of system required.

The one factor that will limit the development of drip irrigation is lack of clean water. A tremendous effort must be made in developing a filtration system that is efficient, economical to use, inexpensive to buy and effective. Thousands of emitters can be placed on the market, but unless good filtration is provided to put clean water into the irrigation lines to prevent clogging of emitters, the system will be of little value.
Drip irrigation in California would not be at the stage of development it is today if it had not been for the fine cooperation between growers, manufacturers, USDA research personnel, and the University of California. There are so many individuals that have contributed to the development of drip irrigation that it is difficult to list everyone without omitting someone who has played an important part in its development.
This was a project where everybody had to learn together. We experimented in the field with various crops, manufacturers experimented with manufacturing techniques and equipment design, researchers put together all known irrigation principles to try to come up with a satisfactory program for experimentation, and the growers were willing to donate land, trees, money, and time to see if this new system had any merit.
It appears that drip irrigation had caused considerable interest among many people in many countries, growing many crops. It is another method of applying water to

WORLDWIDE DRIP (TRICKLE) IRRIGATION SURVEY
Summary of 1974, 1975, 1976, 1980 and 1985 (Est.)

U.S.A.	Acres					
State	1974	1975	1976	1980	1985 (Est.)	Crop
Alabama	7	30	20	2,000	10,000	Tomatoes, Misc. Vegetables, Pecans, Peaches, Vines
Alaska				10	50	Vegetables, Field Crops, Vines, Orchards
Arizona	5,000	6,600	5,225	3,800	5,000	Orchards, Vines, Home Landscaping, Mine Tailing Slopes
Arkansas		210	650	3,000	5,000	Orchards, Vegetables, Blueberries
California	40,000	60,000	70,750	200,000	500,000	Orchards, Nuts, Vegetables, Field Crops, Nursery, Vines
Colorado	5	50				Deciduous, Nuts
Connecticut				10	10	Greenhouses
Delaware	5	50	100	100	500	Orchards, Vegetables, Field Crops, Nursery
Florida	6,000	17,000	28,570	45,000	75,000	Vines, Orchards, Vegetables, Nurseries, Field Crops
Georgia	82	300	450	8,500	20,000	Orchards, Vegetables, Vines, Blueberries
Hawaii	12,500	17,000	46,060	40,000	90,000	Sugar Cane, Macadamia, Field Crops, Vegetables
Idaho		125		400	600	Orchards, Vegetables
Illinois				500	1,000	Orchards, Nurseries
Indiana	40	75	80	80	300	Orchards, Vegetables
Iowa			3	200		Vegetables
Kansas		20		100		Vegetables, Orchards
Kentucky	5	----	----	----	----	No drip installed
Louisiana	20	30		225	500	Orchards, Vegetables, Vines
Maine				50	500	Orchards
Maryland		14		200		Nurseries, Orchards
Massachusetts				100		Vegetables, Orchards
Michigan	3,000	6,000	10,000	60,000	80,000	Orchards, Vegetables, Vines, Blueberries
Minnesota		10				
Mississippi	----	----	----	----	----	
Missouri	60	1,100	1,230	300		Vines, Vegetables, Orchards
Montana				300	2,000	Orchards, Vegetables

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WORLDWIDE DRIP (TRICKLE) IRRIGATION SURVEY
Summary of 1974, 1975, 1976, 1980 and 1985 (Est.)

U.S.A.	Acres					
State	1974	1975	1976	1980	1985 (Est.)	Crop
Nevada		20		30	100	Nurseries, Field Crops, Vegetables
New Hampshire		5				
New Jersey		60	70			
New Mexico	400	965	500	1,000	1,500	Orchards, Vegetables
New York	150	141		300		Orchards, Vegetables
North Carolina	30	50	100	275	550	Vines, Greenhouses, Orchards, Vegetables
Ohio	5		50	200		Vegetables, Strawberries, Orchards
Oklahoma		40	40	637	1,000	Orchards
Oregon	325	500	1,000	1,400	1,500	Landscaping, Orchards, Berries
Pennsylvania	55	50		3,300	5,000	Orchards, Vegetables
Rhode Island	----	----	----	----	----	No drip installed
South Carolina	12	35		430	2,000	Orchards, Vegetables
South Dakota	2	2	1	15	50	Vines, Orchards, Vegetables
Tennessee				300	3,000	Field Crops, Orchards, Vegetables
Texas	3,000	21,000	16,550	10,000	20,000	Orchards, Vegetables, Field Crops, Vines, Nursery
Utah	100	100		700	1,000	Orchards, Vines
Vermont		2	10	100	100	Orchards
Virginia		25	10	300	500	Vegetables, Orchards, Berries
Washington	1,000	1,500	1,500	3,030	12,000	Berries, Orchards, Vines, Hops
West Virginia				150	350	Orchards, Vegetables
Wisconsin			200	357		Vegetables, Orchards
Wyoming			15	200	300	Nursery, Trees

	1974	1975	1976	1980	1985	
TOTAL U.S.A. ACRES	152,511	133,109	183,184	596,219	839,410	

FOREIGN COUNTRIES	1974	1975	1976	1980	1985 (Est.)	Crops
Argentina		375		500		Orchards, Vines, Vegetables
Australia	25,000	42,840	13,330	15,000		Orchards, Vines, Nurseries, Vegetables, Field Crops
Brasil		909		1,000		Orchards, Vines, Nurseries
Canada	500	1,000	25	50	200	Orchards, Home Gardens
Cypus	400	1,000				
Costa Rica		25				
France		3,050	18,035			
Honduras		5				
India		50				
Iran		2,000				
Israel	15,000	25,000	50,000			
Japan		10				
Mexico	16,000	13,826				
Martinique, F.W.I.		1,000				
New Zealand	2,000	2,682				
Panama		2				
Puerto Rico		181				
South Africa	8,600	18,000	18,000	11,000	19,000	Orchards, Vegetables, Field Crops, Vines
Italy			6,177			
Tunisia			70			
United Kingdom		4,000				
West Africa (Senegal)		1,000				
TOTAL FOREIGN COUNTRIES	220,011	250,064	290,151	623,769	858,610	

Total Acreage

	1974	1975	1976	1980	1985 (Est.)
U.S.A.	152,511	133,109	183,184	596,219	839,410
Foreign Countries	67,500	116,955	106,967	27,550*	19,200*
TOTAL WORLDWIDE	220,011	250,064	290,151	623,769	858,610

*Survey Figures from foreign countries incomplete

plants. In many cases it has been a refinement in the use of water. Where water is of poor quality due to high salts, there is a better manipulation of the salt in the soil. Where terrain is a factor, drip irrigation makes irrigation relatively simple. Where labor is a factor, both in availability and cost, a fully automated drip irrigation system eliminates the need for labor except on a very limited scale. With proper development, drip irrigation could be the most efficient, effective, and ecologically sound type of irrigation that is known today.

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