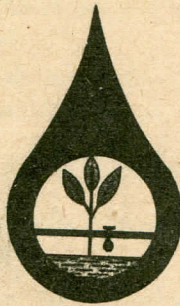


**PROCEEDINGS OF THE SYMPOSIUM ON DRIP IRRIGATION IN  
HORTICULTURE WITH FOREIGN EXPERTS PARTICIPATING**

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## THE LATEST DEVELOPMENTS IN DRIP CULTIVATION PRACTICES

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**ABSTRACT.** Point source emission or drip irrigation, is a low pressure /rather new/ method of irrigation, water is being discharged at very low rate from emitters wetting portions of the soil by a combination of gravity and capillary move forcing each emitter to form a wetted „onion”. The two greatest inovations in this system are: a/ the possibility to irrigate at frequent intervals /daily or twice weekly/ and b/ to apply fertilizers at ease with the irrigation water. Other advantages include: a partial wetting of the soil. Low matric tension allowing for relatively high osmotic or saline water, high control of moisture availability and application. Favourable aeration conditions. The most important outcome, high yields with relatively low water demand. Crops are grown under potential transpirational conditions. There is great ease to determine consumptive use both for design and for practical use. May be used on row crops and plantations.

### DRIP IRRIGATION

#### 1. General

In recent years, a new method of water application — drip irrigation — has aroused considerable interest throughout the world. It involves the lateral spread of water on the irrigated surface by conducting the water under pressure to a relatively closely-spaced grid of outlets, and discharging the water through these outlets at virtually zero pressure. The system generally includes an arrangement for injecting a fertilizer solution into the irrigation water.

This method has many advantages, especially in arid regions characterized by poor saline soil, saline irrigation water, and high evapotranspiration rates. The advantages are: a/ marked increases in crop yields, often double or more than that obtained with sprinkler or furrow irrigation; b/ crop growth which could not be obtained under normal irrigation conditions due to salinity damage; c/ shortened growing season and earlier crops. The major agricultural successes achieved under the adverse conditions of the Arava desert in Israel are undoubtedly attributed to the use of drip irrigation.

The drip system consists of the following components:

- a. A control unit which includes a riser valve, a pressure guage, a water meter and a filter.
- b. A fertilizer dispenser through which part of the irrigation water flows, carrying with it the required dosage of nutrient solution.
- c. A main or feeder line connected to the fertilizer dispenser to convey the water to the secondary lines.
- d. The secondary lines, or laterals, which consists of 12 or 16-mm diameter polyethylene tubing, and on which the nozzles or orifices are mounted at spacings of 50 to 100 cm.

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Drip irrigation may be considered as a form of furrow irrigation. However, it differs in the following features which make the new system advantageous, particularly under desert conditions:

- a. It does not require the opening of furrows at a certain gradient and hence does not call for any of the skills of levelling normally associated with furrow irrigation.
- b. There is no surface flow of water along the furrows and hence no soil erosion or tail-water loss.
- c. The nozzles discharge the water by dripping along the length of the plant row, each nozzle releasing approximately the same quantity of water /pressure losses along the lateral are minimal/. Hence, water distribution is highly uniform and fully controlled.
- d. Application rates can be adjusted by using a different size nozzle with a higher or lower discharge; distances between nozzles along the lateral and between the laterals can be varied in accordance with soil and crop conditions.

There are good indications pointing to a relationship between crop response and decrease in moisture tension, with yields increasing markedly as the interval between irrigations is reduced. Furthermore, it has been found that under desert conditions where evapotranspiration is high and the soil coarse and of low water-holding capacity, daily irrigations or even more than one irrigation per day, produces the highest yields. In this context, it should be noted that in drip irrigation, where systems are usually stationary, several applications can be given daily, whether manually or by use of automatic controls, with practically no additional labour. Frequent irrigation has, of course, the effect of keeping soil moisture tension low, i.e. at about field capacity level. Hence, the crop is able to withstand the higher osmotic tensions inherent in waters of high salinity. The negative effects of poor aeration, often encountered in fine-textured soils, from maintaining a high water content do not occur in the coarse desert soils, and for this reason it appears that the drip method is most suited to these conditions.

The rate of vegetative growth under drip irrigation has been found to be considerably greater than under sprinkler irrigation. This accelerated growth expressed itself in two forms: it led to earlier, as well as higher, yields and consequently to higher product value. Earlier yields also have the effect of lowering production costs since this generally enables the number of irrigations, pesticide applications and other treatments to be reduced.

In the above, only the effect on yield and the moisture tension aspects of drip irrigation have been discussed, and only very briefly. However, a number of other observations, such as the effect on vegetative growth, foliage chloride content, plant root distribution, soil salinity, and the influence of orifice discharge and lateral spacing have also been carried out. The results of these observations indicate that drip irrigation in all respects is advantageous over methods considered.

## 2. The imperative union of fertilizer application and water application

It is not fully realized, and indeed, there is a tendency, to divorce the drip irrigation techniques from the application of fertilizers to the plants. This is totally wrong and dangerously misleading.

Giving a little thought, one should realize that by applying fertilizer in the conventional way /broadcasting, burying or spreading surface-wise/ one compels a complete conflict between the „restricted” drip irrigation water application philosophy and the conventional practice of fertilizer application. So much so, that under these conditions only a small fraction of the fertilizers would random-wise get in touch with the water applied and the fertilizer efficiency will be extremely low. It is therefore, important to note that there is poor identity between the efficient drip irrigation application and the very poor fertilizer use. Many of the drip irrigation apparent failures are the outcome of this discrepancy.

On the other hand, as a complete contrast, outstanding results are obtained when fertilizers are applied /as should be done/ by inserting the fertilizers into the fertilizer dispenser thus injecting it into the system with the irrigation water. The process is: where the water goes the fertilizers follows. This is a highly efficient form of fertilizer application and may be described as follows: there is a complete identity between the root environment, the wetting pattern and the fertilizer availability. It could be said that where the water „goes” there is the root environment and where the water „goes” the fertilizer „goes” making the trio highly identical.

Fertilizers should be applied into the system in such a way and in such combinations, as not to contribute to clogging. The principle is the Hoagland solution but Goldberg and Rimón 1974, have made several concrete suggestions as to „what” and „how” to apply the fertilizers to avoid clogging. These suggestions have been most successfully used in our Israeli, Arava desert practices with agricultural results of 200 tons of tomatoes per hectare as mentioned.

## 3. Potential transpiration and consumptive use

By irrigating at relatively short intervals /daily to twice weekly/ the soil water content in the root zone is continuously kept at about field capacity and the water tension is 0.3 to 0.5 bar. Such an irrigation regime has been found to produce excellent results, and is readily achieved by drip irrigation by which it is possible to apply small quantities of water at any desired interval. It is not practically possible with the gravity or sprinkler methods since large quantities of water would have to be applied, and considerable labor expended.

Drip irrigation creates a condition which can be called „potential transpiration”. In order to clearly define this term, we must first consider the condition known as „potential evapotranspiration” /ETp/. This has been defined by Penman as the consumptive use from a sodded field with unlimited moisture availability. Although the provision of such a condition to agricultural crops is not considered practical

/except perhaps for very short periods/, it is a useful concept for determining actual consumptive use.

Penman's original definition was later modified to apply to cases where soils are wetted to field capacity or more and the plant root zone is at field capacity or more. In such a situation, the atmosphere's moisture requirement will be fully satisfied. In other words, the plant-soil system will not interfere with the transfer of moisture to the atmosphere.

Numerous studies have been carried out on the subject of potential evapotranspiration, among them are those by Penman/1948/, Stanhill/1962a/, 1962b/, Pruitt and Angus/1961/, Pruitt/1964/, Christiansen/1967, 1969/.

The Class A pan appears to be the most suitable indicator for determining the consumptive use of crops and potential evapotranspiration. A very high correlation has been found between ETp and pan evaporation. Derman/1948/ found that the ETp/E pan ratio for grass was 0.6 during the period November-February, 0.7 for March, April, September and October, and 0.8 during May-August. E pan was measured in small, sunken pans. Stanhill/1961a/ found the monthly ETp/E pan relation for alfalfa to be  $ETp = 0.70 E \text{ pan} + 0.47$ , and for weekly periods,  $ETp = 0.75 E \text{ pan} + 0.36$ . Pruitt and Angus/1961/ found that the daily ETp from irrigated perennial ryegrass equalled  $0.67 E \text{ pan} + 0.45$  for the period January-May, and  $0.77 E \text{ pan} + 0.03$  for July-December. Pruitt/1964/ found that the monthly average of ETp for January-May equalled  $0.79 E \text{ pan} + 0.08$ , and  $0.76 E \text{ pan} - 0.02$  for July-December. In general, ETp/E pan can be considered to fall between 0.60 and 0.80. For practical field use, we would recommend basing the determination of ETp on a coefficient of 0.75.

Until now we have discussed potential evapotranspiration. But what is potential transpiration? The principle in drip irrigation is to apply water at relatively frequent intervals so that the soil water tension never exceeds 0.5 atm. Water is emitted by the drippers at a rate of 2 to 4 liters/h. The wetted soil surface is almost totally shaded by the plant foliage and as only a small part of the total soil area is wetted, the loss by evaporation is almost eliminated. This creates a unique situation: water is continuously available in the root zone, while there is little /if any/ evaporation from the soil surface. The evaporation component in the term potential evapotranspiration almost ceases to exist. Moisture is thus lost to the atmosphere only due to transpiration.

Penman/1956/made two very important observations:

1. „For complete crop covers of different plants having about the same color, i.e. the same reflection coefficient, the potential transpiration rate is the same irrespective of plant and soil type.
2. This potential transpiration rate is determined by the prevailing weather”

From this it can be concluded that the consumptive use is almost independent of the crop if the crop is cultivated under conditions of low soil water tension, such as with drip irrigation.

Concerning the values of potential transpiration, we know the following:

1. The values of potential transpiration,  $T_p$ , should in all cases be smaller than those of potential evapotranspiration,  $ET_p$ .
2. Since  $T_p$  is fully dependent on the plant's ability to transpire, there must be some difference between crops in the transfer of moisture to the atmosphere.
3. For design purposes, the  $T_p/E$  pan ratio may be taken as 0.70.
4. A somewhat new approach to soil-water relations

It is generally accepted that four major conditions must be met in order to achieve optimum crop growth: a. moisture availability in the root zone, b. fertilizer availability in the root zone, c. well-aerated soil and d. soil conditions which will form a firm grip to support the plants.

Irrigation is concerned mainly with the first factor, and due to the recently-developed methods of water application it is possible to supply water to the plants at will with great precision and control.

The „total potential”, or total stress, in the root zone consists of the following components:

1. Gravitational potential – the gravitational increment to which water /or moisture/ is subjected in the gravity field.
2. Pressure potential – any pressure developed by the soil water. This occurs under artesian conditions, and is normally harmful to crop growth.
3. Matric potential – originates in the solid phase and represents the moisture availability in the soil. It is 0 when the soil is saturated and increases gradually as the soil dries, reaching several atmospheres when the water available to the plants is almost depleted.
4. Osmotic potential – that increment of the total potential due to the effect of dissolved solutes.

For convenience, only the last two components are normally taken into account. The gravitational potential is small in magnitude and can be disregarded. The pressure potential is associated with water pressure which is detrimental for normal crop production, except in the case of rice culture and those situations where subterranean irrigation methods are used. Consequently, total potential or total stress can be considered as the sum of the matric and osmotic tensions.

By drip irrigation it is readily possible to supply water to plants in any quantity and at any frequency, and to maintain a matric tension which never exceeds a level equivalent to that at field capacity. In terms of moisture stress, this means that the matric-tension does not exceed 30 to 50 centibars. Such low tensions can not be maintained by sprinkler or gravity irrigation.

Commercial crops are currently being grown under such low water tensions using drip irrigation, and high yields such as 200 tons/ha tomatoes, 50 tons/ha muskmelons, and 120 tons/ha apples and pears are not uncommon.

### 5. Use of marginal water

There is a tendency to include both saline and sewage water in the same category of marginal water since both types normally contain a high concentration of salts. However, due to the special sanitary and health problems connected with the use of sewage water, the two types will be considered separately.

In Israel, considerable work has been carried out on the use of saline water for irrigation. As stated before, most of the country's water sources are subterranean and are connected in one way or another with lime formation. Consequently, the water is fairly „hard”, containing salts and calcareous deposits.

Water containing up to 300 ppm Cl is considered of good quality and suitable for all purposes. With the ever-decreasing availability of such good water, efforts are being made to exploit water of higher salinity which is normally classified as marginal. Although the use of saline water in Israel began several decades ago, not until today has it been possible to use water of relatively high salinity (2000 to 2500 ppm Cl). This important break-through is due to the development of new techniques which guarantee high yields without endangering soil fertility.

Experimental and commercial fields in the Arava valley of Israel and the El Arish district of northern Sinai have been drip-irrigated with water containing 600 ppm Cl, and 1200 ppm Cl, respectively. The maintenance of low matric tensions has allowed the development of higher osmotic tensions without incurring any injury to the plants. In this way, world-record tomato crops of 200 tons/ha have been obtained under commercial field conditions.

Although the theoretical knowledge on the effect of low tensions has been available for years (Penman, 1952; Hagan, 1956), the use of saline water became possible only with the development of drip irrigation techniques. Furthermore, this ability to exploit highly saline water demands that the entire matter of desalination be re-assessed. The findings of research in the deserts of Israel on this subject of saline water use have been reported in numerous publications.

The problem of sewage water utilization is considerably more complicated. The general attitude throughout the world is that sewage water is a nuisance which must be disposed of, primarily because of its odors and the water resources are so limited it is unacceptable that such enormous quantities of water should not be utilized in some productive manner.

Complete purification is a very costly process and the water obtained is too expensive for agriculture. Two other methods have been used quite extensively. One is to treat the water partially by means of oxidation reservoirs and then to use it for agriculture by gravity. The other, normally undertaken by a national organization, is to allow the partially-treated water to filter through sand beds and finally return to the ground water.

There is reason to believe that partially-treated sewage water may be effectively used with drip irrigation after it has been gravel filtered. As mentioned above, the low matric increment in the total water tension allows for the high salinity normally present in sewage effluent. Furthermore, the use of this irrigation method obviates the need for the irrigator to come in direct contact with the water and thus reduces the health hazard.

A multi-disciplinary group of scientists, including irrigation engineers, soil scientists, sanitary engineers, bacteriologists, virologists and agronomists, is currently studying the use of semi-treated sewage for vegetable production based on drip irrigation. The results obtained to date are quite encouraging.

## 6. Crop response

Results with drip irrigation have shown a direct relationship between crop response and soil water tension with muskmelon plants, yield increased markedly as the interval between irrigations was reduced. Furthermore, under desert conditions where evapotranspiration is high and the soil is coarse and of low water-holding capacity, daily irrigations or even more than one irrigation per day produce the highest yields. It should be noted that in drip irrigation, where systems are usually stationary, several applications can be given daily, whether manually or by use of automatic controls with practically no additional labour. Frequent irrigation has, of course, the effect of keeping soil moisture tension low, i.e. between field capacity and saturation. Hence, the crop is able to withstand the higher osmotic tensions inherent in waters of high salinity. The injurious effects of poor aeration often created in fine-textured soils by maintaining high water availability do not apply to the coarse desert soils, and for this reason it appears that the drip method is most suited to such soils.

Irrigation applications and the yields obtained in trials carried out on tomatoes, cucumbers, muskmelons, peppers, and sweet corn under drip, sprinkler and /in one case/ furrow irrigation are listed in Table 1. It is not possible here to give full details or a thorough analysis of the trials and the results obtained. However, the table shows that in all cases the yields under drip irrigation far exceeded those of sprinkler and furrow irrigation, and in some cases, they were more than doubled. The quantities of water applied to any particular crop were identical or less for drip irrigation compared to the other methods. Phenological observations were carried out on pepper plants after 110 days of growth, and the results are shown in Table 2. From these results of vegetative development it can be seen that the rate of growth under drip irrigation was considerably greater than under sprinkler irrigation. This accelerated rate of growth expressed itself in two ways:

Table 1. Crop yields under drip, sprinkler and furrow irrigation

C r o p	Period of growth	Water application		Yield, tons/acre	
		inches	Drip	Sprinkler	Furrow
Tomatoes	Sept. - March	38.7	26.7	15.6	—
Cucumbers	Sept.-Dec.	26.4	19.6	0.0	—
Muskmelons	Aug. - Dec.	25.	17.2	9.6	9.6
Peppers *	Sept.-March	55.8	3.8	1.9	—
Sweet corn	Feb. - May	26.6	4.9	2.1	—

\* Under plastic cover during Dec. - Jan.

Table 2. Vegetative growth of pepper plants after 110 days under drip and sprinkler irrigation

P a r a m e t e r	Drip irrigation	Sprinkler irrigation	Level of significance
Number of leaves	65	47	5.0
Number of branches	3	2	0.1
Plant height, inches	11.8	6.6	0.1
Depth of tap root, inches	8.5	6.0	1.0
Diameter of root stem, inches	0.46	0.28	1.0

it led to earlier and greater yields and consequently to a higher product value. Earlier yields also have the effect of lowering production costs, since this generally enables the number of irrigations, pesticide applications and other treatments to be reduced.

Particular attention should be given to the tomato yields obtained under drip and sprinkler irrigation /Table 3/ using saline water with an electrical conductivity of 3 000 micromhos/cm, and a good quality water with an electrical conductivity of 400 micromhos/cm. Drip irrigation gave higher yields than did sprinkler irrigation, irrespective of the water quality. Moreover, under drip irrigation, there was practically no difference in yields between the low and higher quality waters.

Table 3. Tomato yield /tons/acre/ under drip and sprinkler irrigation with good and poor quality water

Irrigation method	High quality water	Saline water
	E.C. = 400 micromhos/cm	E.C. = 3 000 micromhos/cm
Drip	26.7	26.0
Sprinkler	20.8	15.7

In the above, only the effect on yield and vegetative growth and the moisture tension aspects of drip irrigation have been mentioned, and this only briefly. However, a number of other observations, such as foliage chloride content, plant root distribution, soil salinity, and the influence of orifice discharge and lateral spacings have also been carried out. The results indicate that drip irrigation, in all respects, is advantageous over the other methods studied.

#### 7. The latest innovations in drip irrigation practices

Being a very dynamic subject, constantly searching for replies to agricultural practices, several most distinct improvements have been achieved.

It should be noted that the improvements were both in practical application practices, and also improvements in drip cultivational concepts, all leading to greater crop yields, improved quality, timing and control of crops and more universal practical use.

It seems that we are still improving, this is not the end of the road.

I would like to mention some of the innovations:

#### Filtration

The classical static filters are in full use, having assumed a certain design pattern, consisting mainly of a cylindrical non-rusting mesh to hold back unnecessary impurities.

The fault is that when water contains high impurities, water from rivers, from drains, from reservoirs and open sources, these filters clog at an unpractical rate, thus hindering the accepted practices.

The new „dynamic” filtration units, invented and practiced in Israel, have been tried by me on river waters and on water from drains in Surinam, in Tapachula, Mexico, and in the rivers in Panama, have proven to be continuously self-cleaning and constantly in operation with minimal attendance.

I consider this innovation highly important, thus opening drip cultivational practices to additional wide horizons.

#### The low water tension in the root environment

We all maintain, that one of the most important features of the classical drip irrigation practices /see above/ is the maintenance of the low-moisture-tension principle within the root environment of plants.

This is what we managed to get /and indeed we are still getting/ with drip irrigation /correct/ practices.

The question that has been asked and indeed a reply had been given, is, must we use only „classical” drippers in order to achieve those optimal conditions?

The answer is no ! We can achieve it with several other types of equipment, at times in an improved way and with better results.

Theoretically we can apply „low tension” by applying water with a common spoon. Alternatively, one can water sugar-cane /I did it in Barbados/ grown in a pot with an ordinary hose, by applying water /and fertilizers/ at frequent intervals. We all can do it! So the principle of drip irrigation can and should be applied by other means, when the cultivational conditions are right.

Citrus/ and other sub-tropical plants/ develop /in addition to the main root system/ a fine „hair” of roots, close to the surface, adjacent to the upper soil, spread continuously under the foliage. These hairy roots are essential to the proper growth of the plant.

It was observed and experimentally established that the wetting, and maintaining „low moisture” tension in this „hairy” root environment is essential.

One does not need too much of an imagination to conclude that drip irrigation with the classical drippers, is not the best solution.

With drippers is difficult to cover a „surface”.

This is how the solution came with the introduction of low yield, mini-sprinklers or alternatively spitters.

The Israeli market is full of mini-sprinklers and spitters that serve this purpose with success.

It now seems that some of these systems are cheaper than the conventional layouts.

### The vibrating pressure compensating, self-cleaning drippers

New slightly non conventional drippers, came out on the market which look like a small button, attached on the outside of the pipe. Water moves through a „ring” labyrinth and is pressure controlled by a „high quality” rubber diaphragm.

There are several drippers, pressure controlled by rubber diaphragms.

In this case when the system assumes the required minimal pressure of say 1.2 atmospheres, the pressure regulation comes into action and the diaphragm commences to vibrate.

This is very important!

The vibration causes, actually two things: a/ The dripper commences to shriek with a high tone, thus „informing” that it went into „operation” and b/ because of the vibration, it shelves continuously any sediment that sticks, thus maintains the dripper, constantly clean.

Pressure regulated drippers, if reliably constructed, may considerably cheapen a system. If excess pressure exists or if there are sections in a system with an excess pressure, such as the ones closer to the pumps, this excess pressure may be used in order to lengthen the laterals and to widen the intervals between sub-mains.

In short this is a positive design feature which gives greater flexibility.

Pressure regulated drippers relieve a system of pressure regulators, which cost money and cause /at times/ maintenance and operational anxieties.

### 8. Final remarks on drip irrigation

The following are the specific features characterizing drip irrigation potential possibilities:

1. Cultivation under continuous low matric tension in the root environment. Growth under potential transpirational conditions.
2. Cultivation with fertilizer application given with the irrigation water. A union between moisture availability and fertilizer availability. A very efficient fertilizer use.

3. Strip moisture availability and therefore: a/ partial wetting of the soil, b/ continuous and selective aeration on all soils including of heavy texture, c/ dry strips between wetted strips, allowing for mechanical cultivation uninterrupted at all times, d/ partial wetting decreases weeds.
4. Low matric tension allows use of saline and sewage water.
5. Cultivation under potential transpirational conditions eases direct computation of water demand, controls water application and makes good use of class „A” pan.
6. Increases yields and reduces water demand. There are good indications of obtaining earlier fruition.
7. Drip irrigation systems could be readily automated.
8. Good effect of methyl bromide disinfectant applied through drip systems.
9. Promising results obtained through the drip system by applying water of higher caloric value to spread energy on cultivated fields to encourage growth and to combat frost. Solar energy by means of solar heaters could also be used.
10. Crops requiring temporary moisture stress, cotton for strength, sugar crops for concentration of sugar and deciduous fruits for quality etc., water and fertilizer interruptions may be readily applied.