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THE DEVELOPMENT OF IRRIGATION AND FERTILIZATION SYSTEMS IN THE PROTECTED GROWING OF VEGETABLES[1/]

by

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1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

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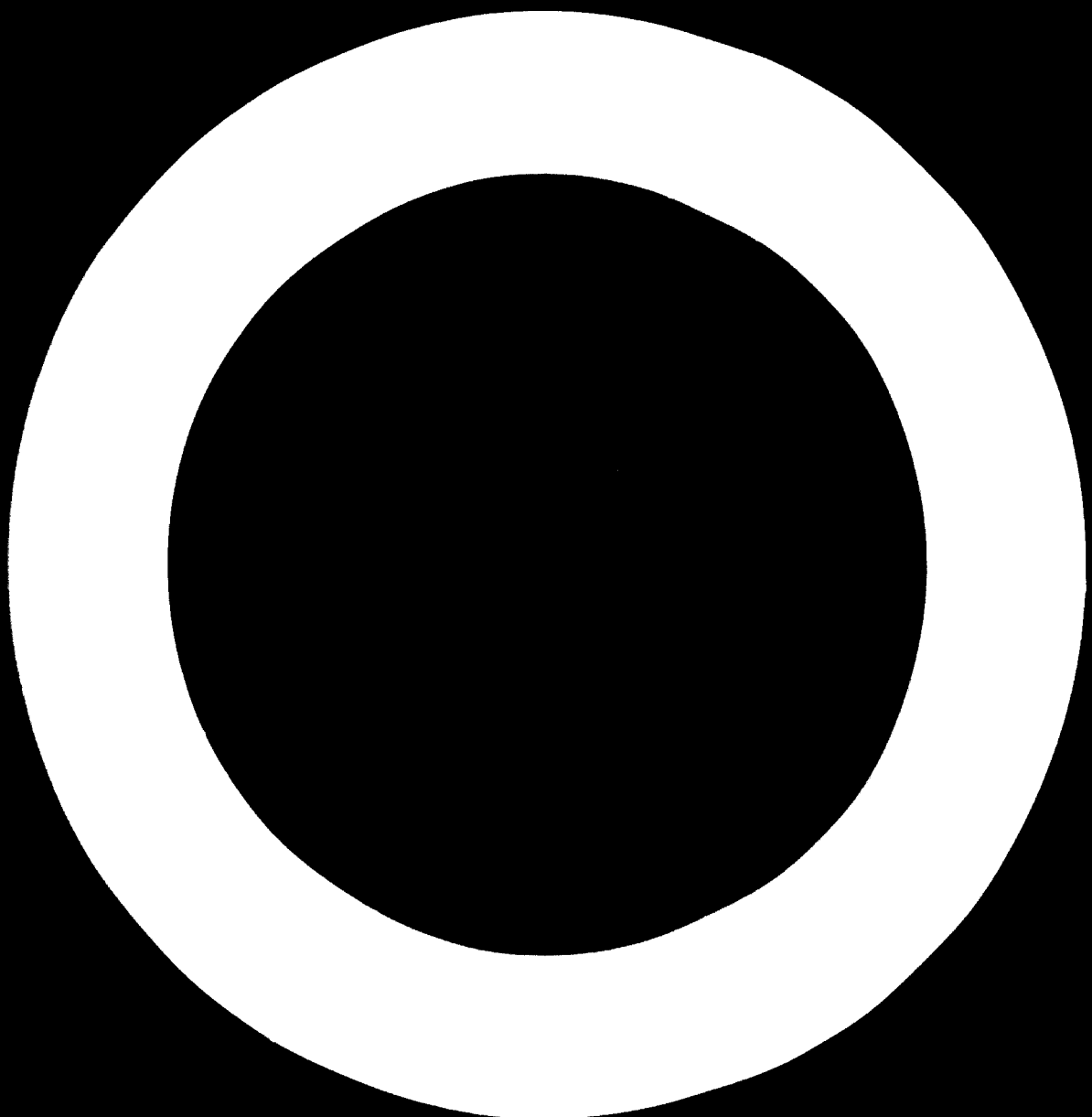

INTRODUCTION

In many regions of the world where the pattern of rainfall is irregular, surface irrigation through furrows has been in use for several centuries.

It was quite natural that when protected crops were first introduced some fifteen years ago the market gardener should have applied the traditional methods of irrigation in his greenhouses. Today, while furrow irrigation may have virtually ceased to be used in heavy glass greenhouses, it is still very widely employed with plastic-covered ones. The grower often considers such large but light protective shelters an improvement over the open-field farming method. He is anxious to hold investment to a minimum, and frequently he is reluctant to install a rather more elaborate irrigation system.

Surface irrigation, however, is not without its drawbacks unless the soil is of the proper texture. In the case of light, coarse, sandy or gravelly soils, which offer excellent permeability, the plants are well supplied with water because:

(a) The entire water supply is available to the plant. The quantity could be easily checked by means of meters, although monitoring of this kind is very rarely used;

(b) The soil's salinity level can be easily maintained;

(c) There is good circulation of air and water. Additionally, such soils warm up quickly in the spring, resulting in earlier crops.

With soil that is more compact and occasionally silty and hard-packed, it is more difficult to ensure that the plants will receive an adequate supply of water. Such soils are very often found in areas under intensive vegetable cultivation - valleys or plains where there are abundant sources of water but where the soil consists of very fine-textured alluvial deposits.

We are quite familiar with soils of this type since, according to the samples analysed, the soils at the Mas Planc Experimental Horticultural Station at Alénya display the following physical composition:

Clay	6 to 9	per cent
Fine silt	10 to 17	per cent
Coarse silt	14 to 20	per cent
Fine sand	30 to 40	per cent
Coarse sand	20 to 30	per cent
Organic matter	1 to 2.5	per cent

All the tests described below were carried out during three consecutive years inside large semi-circular greenhouses covered with a double layer of polyethylene and measuring 50 metres in length by 8.50 metres in width.

In these different experiments the quantities of water delivered were identical for the various methods and were calculated according to the formula developed by the Montfavet Bioclimatological Station for the total radiation penetrating within the greenhouse:

$$\text{MET greenhouse mm/joules} = 0.67 \frac{G \text{ greenhouse}}{L} - 0.2,$$

where MET is the maximum evapotranspiration, in mm;
G is the total radiation, in cal/cm^2;
L is the latent heat of vaporization, 60 cal/mm/cm^2.

TEST ONE

COMPARISON OF IRRIGATION OF A TOMATO CROP BY SURFACE FURROWS AND BY SPRINKLING (Spring 1972)

(a) Experimental layout

The greenhouse was divided into two sections of equal length, that is, two compartments measuring 23 by 8.50 metres.

Compartment one: conventional irrigation by surface furrows

Compartment two: irrigation by sprinkling by means of two perforated pipes located above the plants.

(b) Cultivation data-sheet

Variety: Montfavet H 63-4

Sown on 29 December 1971

Planted out on 14 January 1972 into 11-by-11 plastic pots

Planted on 21 February 1972 in double rows with intervals of 0.25 m between plants and with a spacing of 1.10 and 0.80 m between rows

Plant grown on a single stalk and pinched back at the fifth node

Warm-air heating from 21 February to 9 May 1972; minimum temperature: 14 to 15°C

Harvested from 29 April to 2 May 1972

(c) Results

The results achieved are summarized in the table below.

Methods	Date harvest begun	Cumulative yields in kg/m²							Average weight of fruit in grams
		2/5	10/5	17/5	23/5	31/5	7/6	14/6	
Surface furrows	29 April	0.20	2.25	3.78	6.04	9.34	10.53	10.72	94
Sprinkling	2 May	0.08	1.94	3.67	5.94	9.46	10.60	10.81	89

(d) Comments

Whereas there is little difference between the total yields produced by the two methods of irrigation, the average weight of the fruit is higher and it ripens earlier in the plot irrigated by surface furrows. Moreover, with surface irrigation by furrows it is simpler to check on the health of the plants, and, in particular, attacks of botrytis can be more easily brought under control.

Identical findings were made in the case of melons, pimento and eggplant. Sprinkling the leaves of these plants leads to the appearance of certain parasites, so that the sprinklers need to be placed beneath the foliage. Lettuce alone appears well suited to this method of irrigation.

For silty and hard-packed soils, whether watered from furrows or by sprinkling, beginning at the fourth or fifth irrigation, the following general observations can be made:

(a) The soil tends to become quite badly compacted;

(b) It is practically impossible to check the amounts of water delivered. A large quantity fails to soak into the ground and runs off outside the protected area, carrying with it the fertilizing elements;

(c) Unless the ground is perfectly flat, ponding may occur for several days at the base of the plants.

Localized irrigation provides a means of minimizing these various drawbacks.

STUDY OF SEVERAL TYPES OF LOCALIZED IRRIGATION

As the name indicates, localized irrigation consists in watering only a limited area adjacent to the plants. Water is not delivered to the entire soil area as is the case with sprinkling and very often with furrow irrigation.

Irrigation systems may be divided into two main groups:

1. Those which provide an instantaneous flow rate corresponding to heavy rainfall in the order of 40 to 50 mm/h;

2. Different "drop-by-drop" systems, which deliver to the plant very small amounts of water ranging between 2 and 6 mm/h.

A number of tests conducted at the Station in 1973 and 1974 have enabled us to compare the different systems. These comparisons were made on bare and on mulched soil.

TEST TWO

IRRIGATION OF PIMENTO

(a) Experimental layout

Three systems were compared:

1. Traditional irrigation by means of furrows

2. Local irrigation using perforated pipes

The water is distributed to the plants by means of perforated polyethylene pipes measuring 25/32, with the initial pressure ranging between 0.5 and 1 bar.

The ground is prepared and the plants are set out in such a way that the water is kept near the roots and cannot overflow into the pathways between the rows.

Holes of 2 mm in diameter can simply be made, using heat, every 75 cm along the pipe, or else they can be equipped with 1.6-mm nozzles, which gives improved distribution of the water. These holes are protected by grooved rings slightly larger in diameter than the pipe itself. Flow rates are fairly high and may range between 40 and 50 mm/h. To ensure a more even distribution of the water, the furrows are divided every 2.25 m and the pipes are supported on small cross-pieces to prevent their coming into contact with the ground and the possible obstruction of the holes. The small troughs thus created at the base of the plants receive a uniform quantity of water which seeps slowly into the ground. With this system, the water is delivered at the same rate as with the furrow irrigation system.

3. Localized irrigation by means of capillaries

A flexible polyethylene pipe into which are inserted at 25-cm intervals a series of capillary tubes, 0.7 mm in diameter and 50 cm in length, carries the water between two rows of plants. Each capillary, buried 2 cm deep in the soil along the row, provides the daily supply for two plants. Each capillary has a flow rate of 4 litres at 1 kg of pressure corresponding to an hourly rainfall of 5 mm.

Each of the 23-m-long test areas is divided into two sections: one with bare soil, the other with plastic mulching (the film used being opaque thermal polyethylene).

This test was done twice.

(c) Results

Since harvesting has not yet been completed, the results given below refer to early yields.

Methods		Harvesting of unripe fruit			Harvesting of fruit (unripe + ripe)	
		Yield in kg/m² on 13 June	Average weight of fruit, g.	% of cankered fruits	Yield in kg/m² on 10 July	% of cankered fruits
1. Furrows	Bare soil	1.14	175	19.3	3.18	13.4
	Mulching	1.09	163	26.8	2.86	18.4
2. Perforated pipes	Bare soil	1.07	160	16	3.02	10.4
	Mulching	1.37	179.5	8	3.57	3.3
3. Capillaries	Bare soil	1.11	172	9	3.13	6.1
	Mulching	1.22	167	8.4	3.26	6

(d) Comments

One interesting result of this test that might be immediately noted is the reduction in the percentage of cankered fruits achieved by switching from the traditional method of irrigation to the localized systems. This result is of great importance since, with the soil types in question, necrosis in fruits is caused by improper watering.

TEST THREE

LOCALIZED IRRIGATION OF MELONS

(a) Experimental layout

The irrigation is effected by means of a perforated pipe. The system used is the same as the one described previously under No. 2. The melons are planted in bare and mulched soil.

(b) Cultivation data-sheet

Variety: Vedrantais

Sown on 30 January 1974

Planted out on 6 February 1974 into 11-by-11 plastic pots

Planted on 26 March 1974 at 0.40-m intervals in rows 2 m apart

Grown under a large cold-frame with temporary protection by means of small tunnels from 20 March to 8 April 1974

Traditional cultivation on the flat: dimensions 2 x 8 x 3

(c) Results

Harvesting is currently in progress and will be continued until about 15 August 1974.

Methods	Date harvest begun	Cumulative marketable yields in kg/m^2					Average weight of fruit in grams
		17/6/74	24/6/74	1/7/74	8/7/74	15/7/74	
Bare soil	11 June 1974	0.28	1.17	1.32	1.43	1.56	328
Mulching with opaque thermal polyethylene	10 June 1974	0.86	1.94	2.26	2.45	2.52	384

(d) Comments

The results given above are not final since the harvest is still in progress. However, they confirm the findings made in a large number of tests previously carried out with irrigation by furrows on bare and mulched soil: in the case of melons, mulching has a very marked effect in terms of earlier yields and heavier average weight of the fruit.

INTRODUCTION OF FERTILIZER SOLUTIONS IN PROTECTED VEGETABLE GROWING

For some number of years now, the technique of fertilization through irrigation has been used in horticulture, particularly at establishments specializing in the growing of roses and carnations. This relatively new technique is beginning to attract the attention of market gardeners. We tested it at the Station in combination with the sprinkling and local irrigation methods.

The Versailles Physiology Laboratory under the direction of Mr. Colc informed us of the composition of a fertilizer solution for use with tomatoes. For water with the following analysis:

pH	8
K	0.02 meq/l
Na	1.7 " "
Ca	2 " "
Mg	0.8 " "
S	0.3 " "

the following solution was recommended:

To 1,000 litres of water, add an enriched solution containing for every ten litres:

290 mml	nitric acid
145 grams	ammonium phosphate
85 "	magnesium sulphate
45 "	potassium sulphate
395 "	calcium and magnesium nitrate
555 "	potassium nitrate

To this solution, add 100 mml of a stock solution of trace elements containing per litre:

0.5 grams	ammonium molybdate
15 "	boric acid
40 "	magnesium sulphate
20 "	zinc sulphate
25 "	copper sulphate

Finally, add 10 grams of iron sequestrene.

We might note that all the water supplied to the plants was enriched.

TEST FOUR

FERTILIZING IRRIGATION WITH TOMATOES

(a) Experimental layout

The greenhouse is divided lengthwise to form two plots measuring 23 by 8.50 m:

Plot one: irrigation by sprinkling of the foliage;

Plot two: local irrigation through capillaries.

The system is in every sense identical to the one previously described in test two with pimento.

(b) Cultivation data-sheet

Variety: Montfavet H 63-4

Sown on 27 December 1972

Planted out on 8 January 1973 in 11-by-11 pots

Planted on 20 February 1973 in double rows 0.90 m apart separated by 1.10-m paths

Interval between plants: 0.25 m

Plant grown on a single stalk and pinched back at the sixth node

Warm-air heating from 20 February to 27 April; minimum temperature: 14 to 15°C

With both methods the first two irrigations following planting were by means of a flexible hosepipe located in the planted furrow.

The comparison of the two irrigation systems was begun on 16 March and continued until the end of harvesting, on 16 June 1973.

Frequency of irrigation by sprinkling: Twice weekly

Frequency of irrigation by local capillaries: Daily

In the part of the test involving sprinkling, plants were given a one-minute rinsing with well water to eliminate any salt traces.

The fertiliser solution was fed by means of a "Dosapro" batching pump.

(c) Results

Methods	Date harvest begun	Cumulative yields in kg/m^2							Average weight of fruit in grams
		2/5	7/5	14/5	21/5	30/5	8/6	16/6	
Sprinkling	26/4/73	0.17	1.01	3.20	4.59	7.12	8.41	9.02	84
Local capillaries	26/4/73	0.21	1.12	3.86	5.52	9.03	10.84	11.18	91

(d) Comments

The results shown above are quite positive. They are slightly superior to the results obtained with identical plants fertilized according to the traditional method. At the same time, they give clear evidence of the superiority of local irrigation over sprinkling with respect to both early crops and yield.

FIFTH TEST

LOCALIZED FERTILIZING IRRIGATION WITH TOMATOES

(a) Experimental layout

This test was a follow-up to the one before. The aim was to ascertain, during the spring of 1974, whether localized application of a fertilizer solution with identical composition would confirm the results cited above.

This solution was applied to the plants by means of two systems:

1. The perforated pipe, already described, ensuring heavy flow rates of about 50 mm/h;
2. A true "drop-by-drop" system of the "Netafim" type, whose flow-rate of 2 l/h is equivalent to rain-fall of 2.6 mm/h.

The plants were watered on the average twice weekly with the pipe and daily with the "Netafim" system.

For each of the methods the test was made on two plots: bare soil and soil mulched with opaque thermal polyethylene.

An identical layout was installed in a greenhouse in which the traditional method of fertilization based on soluble fertilizer was used. These two greenhouses were placed side by side in parallel.

(b) Cultivation data-sheet

Variety: Lucy

Sown on 24 December 1973

Planted out on 4 January 1974 in 11-by-11 pots

Planted on 13 February at 0.33-m intervals, with 1 m between rows

Grown on a single stalk pinched back at the eighth node

Warm-air heating: minimum temperature: 14 to 15°C

(c) Results

LOCALIZED IRRIGATION ALONE

Methods	Date harvest begun	Cumulative marketable yields in kg/m^2						Average weight of fruit in grams
		6/5	20/5	31/5	14/6	28/6	5/7	
Perforated pipes:								
bare soil	3 May	0.04	0.64	1.42	4.34	9.26	9.78	84
mulching	3 May	0.02	0.64	1.60	4.82	9.60	10.04	84
Drop-by-drop:								
bare soil	3 May	0.03	0.68	1.74	4.74	9.79	10.11	85
mulching	3 May	0.11	0.64	1.73	4.44	8.92	**9.59**	86

LOCALIZED FERTILIZING IRRIGATION

Methods	Date harvest begun	Cumulative marketable yields in kg/m^2						Average weight of fruit in grams
		6/5	20/5	31/5	14/6	28/6	5/7.	
Perforated pipes·								
bare soil	29 April	0.09	0.78	1.70	5.56	10.20	10.79	85
mulching	29 April	0.11	1.02	2.36	6.22	10.96	11.50	87
Drop-by-drop								
bare soil	29 April	0.13	1.01	2.24	6.09	11.35	11.83	87
mulching	29 April	0.17	1.10	2.42	6.66	11.92	12.29	88

(d) Comments

As in the previous year, the results of this test clearly show the advantages of fertilizing irrigation, which results in earlier ripening, higher end-of-harvest yields and a heavier average weight for the fruit.

On the other hand, the differences are less evident between the two irrigation systems, and although apparent in three cases out of four, the beneficial effect of mulching is far less obvious than with melons.

CONCLUSIONS

From this series of tests, the purpose of which was to improve the water supply of plants grown under protected conditions, the following general conclusions can immediately be drawn.

In the case of light, sandy or gravelly soils, which are particularly suitable for market garden crops, traditional surface irrigation through furrows poses no major difficulties. Entire regions in Europe - Sicily for example - use this method of watering with success. The problems become more intractable when the grower is faced with more silty soils, which tend to block the penetration of water and air.

While it is true that irrigation by sprinkling makes possible a more uniform distribution of the water, it is unsatisfactory for many heavily leafed plants, such as tomatoes, melons, eggplant, and others. Early yields are smaller and cryptogamic diseases, especially Botrytis, are more difficult to control.

The localized irrigation methods which have recently been tried in water-poor countries appear to offer certain valuable advantages:

Since the pathways are protected from the water, the soil remains far looser.

The flow rates provided by these different systems are known accurately enough to permit monitoring of the amounts of water received by the plants.

These systems are relatively easy to operate and maintain, resulting in a saving of manpower.

Together with the use of plastics for mulching, this technique when used with low-growing plants, such as melons, offers a means of achieving considerably more abundant early harvests. As we have seen, in the case of taller plants, such as tomatoes and pimento; the gain in early harvests as a result of covering the soil is not so clear. Although the direct advantages are less obvious, the resultant saving of water should be taken into account: the plastic film limits the soil's water losses through evaporation and thus helps to lower the relative humidity within the enclosure. In addition, excellent weed control is ensured by using opaque material.

The tests conducted, as briefly described in this article, demonstrate that additional progress can be achieved through the use of fertilizer solutions.

These experimental results are very encouraging. The combination of a localized application of water, the covering of the soil with plastic film, and the use of fertilizer solutions will lead to higher gross returns from protected vegetable farming.

This new method of plant watering and fertilization will nevertheless require experimentation on a larger scale together with thorough economic studies before it can be proposed to growers.