DRIP IRRIGATION AND ROOT DEVELOPMENT IN A HUMID CLIMATE AND PROBLEMS OF IRREGULAR DRIPPING

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Introduction

The first trickle irrigation system in the Netherlands was installed in 1974, on 1 ha of commercial orchard. Since then its application rapidly expanded. The development was accelerated by the dry season of 1976 but subsequently was retarded by low fruit prices. At present dripping is being applied on some 450 ha, i.e. on 1,7 percent of the total orchard area only, but a further increase is expected. Recent calculations showed that trickle irrigation in the Netherlands becomes remunerative only, when average annual returns in money resulting from a better yield, exceed 6 percent in years with a high yield and a good price, whereas it should exceed 13 per cent when both yield and fruit price are moderate. With the continuous bad prices of late years, the required effect of trickle irrigation should be at least a 10 per cent better outcome. This condition could more easily be fulfilled when beside a higher yield, watering results in better sized fruit of improved quality because the effect is then augmented by a higher price per kg.

On 84 per cent of the area under dripping the water is withdrawn from 6-60 m deep wells. If often contains much iron, usually 3-15 mg Fe per litre. Problems of outlet blocking are avoided by applying nozzles with high outputs of some 4 l per hour but regular cleaning by acid treatment remains necessary when the content exceeds $\pm$ 6 mg Fe per 1.

Because the profit of investments in trickle irrigation is often questionable, it is of paramount importance to learn how to operate the system in order to achieve optimum results. Considering the moderate climate and the general good water holding capacity of most soils it seems, that trickle irrigation in the Netherlands is doomed to remain a fringe phenomenon. Nevertheless, there are some typical circumstances in Dutch fruit cultivation that make trickle irrigation more important for water supply than it could possibly be at first sight.

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1. Although the climate is temperate, rainfall distribution in spring and summer can be very irregular. Extremely dry seasons with considerable losses to yield and fruit quality occur every 8-10 years.

2. Stunted growth in young apple plantings, caused by replant disease is frequently to be feared.

3. Dense planting of apple trees on the dwarfing rootstock M. 9 renders them more susceptible to drought.

4. The enormous influence of fruit size on the financial outcome necessitates support of fruit growth by watering.

5. In spring frost afflicted areas the double purpose use of overhead sprinkling render it more profitable than drip irrigation but in the south-western part of the country and along the coast spring frost chances are small. In the south-west water can only be withdrawn at low rates from shallow sweet water layers 6-10 m deep, because the deeper water is saline. Drip irrigation with a low water demand then is the obvious way of watering.

6. For utility reasons grass strips in the alleys between tree rows are applied in at least 80 per cent of all plantings. This system requires considerably more moisture than overall herbicide treatment.

7. In some areas near the coast only slightly brackish water is available. In the case of dripping, water with a higher salt content e.g. up to ± 3 g NaCl/l, could possibly be used compared with overhead sprinkling.

Climate

TABLE 1 - *Climatical profile of the Netherlands*

	J	F	M	A	M	J	Jl	Au	S	O	N	D
rainfall mm	65	49	42	45	49	54	77	82	72	73	72	62
evaporation (Penman) mm	5	17	41	77	109	126	119	99	63	31	11	4
daily average temperature °C	1,9	2,1	4,7	8,1	11,9	15,0	16,8	16,8	14,5	10,2	6,2	3,3
sunshine hours a month	52	68	123	164	212	223	202	191	146	101	49	40
relative air humidity	87	85	81	77	75	76	78	80	82	85	87	89
mean monthy radiation KJ. cm^{-2}	7	13	26	39	51	53	49	43	30	18	8	5

Table 1 delineates Dutch climatical conditions but considerable annual deviations occur. For instance, in each of the months April-September rainfall in «normal» years may range between 1/4 and 2 time the quantities presented.

Eo, evaporation from a free water surface (Penman) for the period April-August, in average exceeds precipitation by 223 mm but it may vary between slightly negative and 350 mm. In the extremely dry year 1976 it even came to 450 mm. The alternation of dry and wet periods affects fruit quality. For instance, rain following a dry period of stress causes serious fruit cracking in plums and cherries every two or three years, but sometimes also in apples.

Replant disease

A high share of apples in the total fruit area (75 per cent), a short life-cycle of apple trees (15 years), shortage and at present extremely high prices of agricultural land (D.fl 50 × 10^3; Il 20 × 10^6 per ha) are factors that again and again force the fruit grower to replant apples after grubbing an old apple orchard. At least 85 per cent of new apple trees are planted this way. Replant disease may then prevent normal root development and in particular affects the feeder roots. The resulting stunted growth of the tree can, at least partially, be explained by limited ability of the roots to absorb water.

Apple trees on the dwarfing rootstock M. 9, even when densely planted, have to fill up their space within 4-6 years, otherwise the production level of the grown orchard will for ever remain below optimum. Promotion of juvenile growth therefore is one of the first concerns of the grower. Another factor that counteracts a smooth vegetative development of the young tree is the generally precocious cropping of densely planted trees on M. 9. To diminish the adverse effect of replant disease, the grower more or less successfully fills the planting-hole with potting compost, usually garden peat (a mixture of Sphagnum moss peat and frozen black peat enriched with nutrients), but since the trees are being planted with a clipped root system the young trees are extremely susceptible to drought, Watering them usually becomes badly necessary, particularly in dry periods. Under such conditions trickle irrigation has given its most promising effects, not in the last place because wetting of the organic material in the planting-hole, and the adjoining soil is more completely attained by dripping near the stem rather than by overhead sprinkling. It could be postulated that trickle irrigation, applied right from planting renders the equipment far more paying compared with trickling that becomes operative in an already fully grown orchard.

The effect of replant disease can partly be undone by watering. This was shown in an experiment with overhead sprinkling on Cox's Orange Pippin and Benoni apple trees on M. 9. The soil was a light-textured silt loam. Prior to planting in 1972, part of the experimental plots was fumigated by soil treatment with chloropicrin. Another part of the young trees received garden peat in the planting-hole. Overhead sprinkling was applied in 1973 (159 mm), 1974 (30 mm) and in 1975 (170 mm). In the second year after planting sprinkling resulted in a 53, 11 and 104 per cent higher total

TABEL 2 - *Effect of planting-hole treatment, compost-mulch, and drip irrigation on Jonagold M.9 apples planted in 1977. Experiment in Wilhelminadorp.*

Treatment	Total shoot 1	Yield			
	1977	1978		1979	
	m/tr	kg/tr	g/fr	kg/tr	g/fr
Control	1.5	3.1	240	7.3	244
Drip irrigation	3.0	4.4	209	9.7	252
Mushroom compost-mulch	1.7	3.1	248	8.9	251
Mushroom compost-mulch + dr. iir	2.9	4.6	233	10.0	255
Potting compost	2.9	4.1	214	8.5	244
Potting compost + dr. iir.	4.6	5.7	223	12.8	249
Potting compost + mushroom compost	3.5	5.2	239	9.9	258
Potting compost + mushroom compost + dr. iir.	5.3	6.9	225	12.5	259

shoot production in comparison with non irrigation, for untreated soil, fumigated soil and peat-filled planting-holes respectively. In this order 28, − 7 and 19 per cent higher apple productions were achieved by sprinkling, as an average of the 1973-1975 yield (a negative sprinkling effect points to delayed cropping). Benoni showed similar results: a 31, 12 and 31 per cent increase in shoot length in 1973 and a 43, −3 and 50 per cent higher yield in 1973-1975, as an effect of sprinkling on trees in untreated soil, fumigated soil, and in garden peat-filled planting-holes respectively.

For practical reasons, soil fumigation is not practised in Netherlands. The costs are high, risks are great and planting-hole treatment is an excellent substitute for fumigation. Garden peat or other potting material is generally applied. The favourable effect of supplementary watering under these conditions and the suitability for wetting the content of the planting-hole have largely increased the applicability of trickle irrigation in the Netherlands. Positive effects on newly-planted trees are more determined by the occurrence of long dry periods during the growing season than by a limited moiture supplying capacity of the soil. Because of the frequency of dry periods, effects such as reported above have often been noticed.

Table 2 finally gives an impression of combined treatment effects in an experiment on marine silt loam at the Research Station for Fruit Growing in Wilhelminadorp. After grubbing a former experiment with apple trees, Jonagold on M.9., 1800 trees per ha, were planted in February 1977.

Dripping was applied near the stem. A total quantity of 1128, 560 and 800 1 water per tree was given in 1977, 1978 and 1979 respectively. Potting compost, 20 1, was added to the planting-hole. It diminished the unfavourable effect of replant disease and largely improves the water-holding capacity of the content of the planting-hole. Drip irrigation adds the water. Mushroom compost, a waste product from mushroom cultivation, was spread as a mulch around the stem. It conserves soil moiture. All these treatments were applied to half of the trees. The single and the combined effects of the treatments are very evident. Watering, mainly through better tree growth, in average resulted in a 39 and 30 per cent higher yield in 1978 and 1979 respectively. The effect seemed somewhat augmented by adding organic material to the planting-hole. Merely from the present larger crown size a substantially higher yield of the watered trees can be expected in at least a number of years to come, even when the trickle equipment would be rendered inoperative from 1980. Since the Jonagold variety makes a reasonable auction price, the investment for the irrigation system could easily have been repaid within four years after planting.

Increase in plant density

In the past, simultaneously with an almost complete change-over from vigorous and semi-vigorous rootstocks to the dwarfing M. 9, plant densities of apple orchards have considerably increased. In orchards planted before 1950 tree numbers per ha ranged from 400 and even less to 800. In 1950-1970 this was 400-1600 and after 1970 about 1000-2000. At present, an average number is 1800 trees per ha, e.g. at a distance of 350 × 150 cm in single rows. Some growers even plant 3000-5000 trees per ha.

Quite an amount of evidence has been accumulated on the relative susceptibility of dense plantings to drought. Own observations with tensiometers complemented by soil moisture determinations have shown, that during the growing season a wet soil at 50 cm from the stem dries out the sooner, the more densely the trees are planted. Verhey (1972), in comparing root concentrations at 45 cm from the stem of Golden Delicious trees planted at 90 cm and 230 cm in a row, found a 50 per cent higher root concentration with the first group. Own provisional data further suggest that in single rows the horizontal spread of the root system decreases, and that almost proportional to the inter-tree distance. For single rows this may mean that above a certain plant density the trees will not be able to utilize all the available soil moiture in the middle between the rows.

Although dense planting has substantially raised the production per ha, inter-tree competition for light and moisture and probably also less vigorous growth as a consequence of reduced pruning, form a potential menace to fruit quality. Numerous data point to reduced fruit sizes in dense compared with wide plantings. For instance, in the extremely dry year 1976 the average diameter of Belle de Boskoop apples in a tree spacing experiment in Wilhelminadorp, amounted to 59 mm when the trees were planted in single rows at 395 × 205 cm distance (1110 trees per ha), whereas it was 52 mm only in six-row beds with 3330 trees per ha. A normal diameter for this variety is 80 mm approximately.

Since under the West-European conditions of continuous overproduction of apples, fruit size is as important to financial outcome as production level per ha it is obvious to expect that trickle irrigation by promoting fruit growth, could become a powerful support to maintain a good fruit quality in dense plantings. So far, I know of no comparative experiments in which the financial effect of trinckle irrigation is related to planting systems.

Grass strips

Of the total orchard area in the Netherlands, 5 per cent is considered very susceptible to drought. Another 40 per cent is moderately to slightly susceptible, 40 per cent has a satisfactory water holding capacity and capillary supply from groundwater. The remaining 15 per cent of the area has excellent moisture conditions. This estimation is based on an evaluation of soil profile properties, rooting depth, and ground water level. The main soil management system is grass strips in the alleyways between the tree rows, and herbicide treatment in the tree strips. The grass usually develops from weed vegetations but is sometimes sown. It covers 50-60 per cent of the soil area (row distances 3-4 m). Grass strips consisting of different vegetations, varying from slightly to moderately competitive, can be found in at least 80 per cent of the orchards. Although the productivity of the orchard is sometimes slightly depressed by competition, the grass strip system is maintained even on somewhat dry soils because the improved continuous accessibility of the orchard in periods of excessive rainfall is highly esteemed.

From a view-point of water balance it can be stated, that grass strips certainly have accentuated the need for supplementary watering f.i. by trickle irrigation.

TABLE 3 - *Rainfall and evaporation from a free water surface in the Netherlands and potential evapotranspiration in orchards*

	A	M	J	Jl	Au	S	Total	A-Au
Rainfall in mm	45	49	54	77	82	72	307	
Eo, evaporation (Penman)	77	109	126	119	99	63	530	
Fully productive orchard, overall herbicide treatment								
f = Ep/Eo	0.4	0.6	0.9	0.9	0.8	0.7		
Ep	31	65	113	107	79	44	395	
Fully productive orchard, grass strips								
f = Ep/Eo	0.6	0.8	1.1	1.0	0.9	0.8		
Ep	46	87	139	119	89	50	480	

Table 3 gives a an impression of average potential evapotranspiration Ep in orchards without and with grass strips. In estimating the crop factor f, the influence of the generally applied wind-breaks (Eo in a sheltered orchard = ± 0.9 × Eo in the open field), grass strips, and the aërodynamic roughness of the orchard surface is taken account of.

As can be concluded from the estimated data, potential evapotranspiration in an orchard with overall herbicide tratment in average exceeds precipitation only in May-July (by 105 mm) whereas in an orchard with grass strips this period extends over some 1 – 1 1/2 month more (Ep-rainfall in April-August = 173 mm). This demonstrates that the grass strip system has substantially increased the need for watering, especially on soils with limited moisture capacity.

When moisture losses are to be replenished in orchards without grass, the quantities of water needed for trickle irrigation and for overhead sprinkling are not much different, at least when closed plantings are involved. With sprinkling probably an extra 10 per cent or so, should be given to allow for losses by interception and evaporation.

However, in orchards with grass strips trickle irrigation certainly saves water compared with sprinkling. Because dripping is solely done on the weed-free tree strip, and the grass alley is not watered, crop factors for orchards without grass can then be used, whereas in the case of sprinkling, factors for grass strip orchards shoud be used. Together with the allowance for evaporation and interception losses mentioned before, thi could result in a saving of 20-30 per cent water compared with overhead sprinkling.

Trickle irrigation in mature orchards

Many apple growers have installed their trickle equipment in grown, well-closed plantings. Although not very well-founded, there is a feeling that watering near the stem could be somewhat less favourable to the tree, e.g. because of the risk of root asphyxia. Therefore, the drippers are often placed in-between the trees, i.e. at 0.60 - 1.25 m from the stem. Moreover the trees then profit from water at two sides which is thought to improve the efficiency of watering.

There is a great variation in plant densities (1000-2000 trees per ha, sometimes even considerably more) and in planting systems (single-rows, double-rows, three-rows, beds). Because of the high investments costs compared with the expected results, there is a tendency to limit the number of drippers per tree as much as seems justified. For instance, one per two trees in a dense single-row orchard, or one per three trees in a more-rows system, is sometimes applied. A majority of growers uses drippers with a 4 litre per hour output. There is too little understanding about when to start watering, during how many hours a day, and when to stop after commencement of a period of rainfall. In extremely dry periods some growers have operated their irrigation system during 24 hours a day. This corresponds with almost 100 litres per dripper, or 11 mm daily when one dripper per tree and 1100 trees per net ha are applied. Although these growers report good results, it goes without saying that the greater part of such quantities of water will be lost by deep percolation, since trickle irrigation usually is confined to shallow-rooted, light-textured soils.

However, when the required quantity for the week to come, as is recommended, is calculated on a basis of replenishment of the difference between potential evapotranspiration and effective rainfall in the preceeding week, daily quantities during one-week periods will range between 0 and about 5 mm as a maximum. For the modern densely-planted apple orchard (1800 trees, 1800 drippers per ha) this corresponds with a daily output between 0 and about 30 litres per dripper. In more widely planted orchards (1200 trees, 1200 drippers) the variation then is 0 - about 40 litres.

In the case of trikle irrigation commenced in grown, closed plantings two questions force themselves: 1. What effects upon the yield can be expected, and 2. Does the mode of watering with drippers in-between trees, and daily output rates based on replenishment of moisture losses in the preceding week lead to optimum water supply?

Effects of dripping on mature trees

From experience in commercial orchards and field experiments the impression was gained that it may take some time, one or two years, before trickling becomes fully effective. In years with normal precipitation the response is mainly confined to production of somewhat bigger fruits. With Golden Delicious skin russeting is depressed but as yet there is no distinct evidence that less bitter pit in apples or in general, improvement of keepability can be expected. The increase in production is not so much brought about by more fruits resulting from improved shoot growth, possibly because growth effects are undone by pruning, or are rendered ineffective by increased light competition. Distinct improvements in fruit quality (bigger sized, less cracked fruits) are mainly achieved in dry and extremely dry years such as 1975 and in particular 1976. The profitability of investments for trickle irrigation then depends a great deal on soil moisture conditions and on the occurrence of dry years. The possibility to improve fruit size by watering is of course more highly valued in dense than in wide plantings.

Moistened soil volume, root adaptation, and efficiency of dripping

When dripping to mature trees is applied for the first time, the root concentration under drippers placed in-between the trees may be lower than, or at best is equal to the root concentration near the stem. Although the matter seems to have been too little investigated we may conclude from literature sources (Black and West 1974, Keller and Karmeli 1974) that in case of daily watering in a non-arid area, a minimum of say 20 per cent of the rooted soil volume, or rather of the number of fine roots should be wetted in order to obtain satisfactory absorption of supplementary water. In a modern apple orchard with 1800 trees per ha, and grass strips in the alleyways on a drought susceptible soil, with a supposed rooting depth of 0.6 m, the average total rooted soil volume per tree is stimated at some 2.5 m3. The required volume of wetted soil then is 0.5 m3. The proportion of the rooted soil volume wetted, of course depends on quite a few factors such as number of drippers, intensity of watering (application rate per day and per hour, intervals between drippings), physical soil propertis, rooting depth and root concentration in the wetted zone, water uptake in proportion to supply, moiture content a.s.o. In an experiment with three-year old apple trees, and trickle points in-between the trees (tree distance 2.0 m) an attempt was made to establish a relationship between various daily quantities of water per trickle point and volumes of wetted soil. The soil was a shallow silt loam (18 per cent clay) overlying medium fine sand at 0.6 m depth. The rooting depth also was 0.6 m. The volumes of wetted soil were assessed by moisture determinations in numerous soil samples taken from various depths down to 0.6 m, and at various distances to the trickle point. The sampling was done under cool weather conditions, after several days of dripping and a few hours after termination of dripping. Because the trees were still young, root concentrations in-between the trees were rather low. The variation in daily output rates per dripper was realized within one period by differing both the output per hour and the duration of dripping. «Moistened» was defined as a difference of more than 2 per cent moisture content on a weight basis, between trickled and untreated soil at comparable places. Since the upper soil had lost at least 50 per cent of its moisture between F.C. and P.W.P., part of the «moistened» volume still refers to water at rather high negative potentials.

Figure 1 represents the demanded relationship. Each point refers to one trickle point. Under the conditions of the experiment a «required»

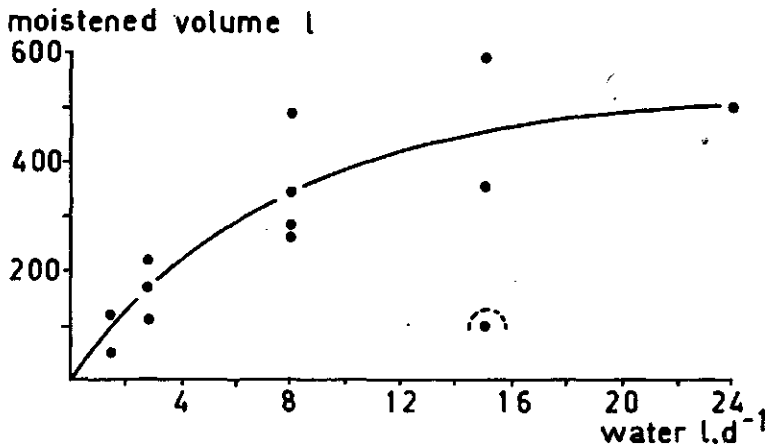

Fig. 1. - Moistened volumes of soil (0-60 cm deep) as related to daily output rates of water. Shallow marine silt loam overlying medium fine sand. Wilhelminadorp, 1974.

wetted soil volume of 0.5 m3 was achieved only at daily rates of at least 15 1 per trickle point. Under orchard conditions the relationship could easily have turned out less optimistic. For instance, a higher root concentration and mature trees resulting in a higher daily uptake of water, output rates more in agreement with actual evapotranspiration, wetted zones on lighter-textured soils, and a definition of «wetted» confined to water at low tensions only, would have resulted in smaller wetted volumes than suggested in figure 1. It may therefore be concluded that under the prevailing Dutch conditions of one dripper per tree only, a temperate climate and replenishment rates based on evapotranspiration diminished by rainfall, with a resulting daily maximum of only 5 mm, as a rule far too small wetted soil volumes will be achieved. It should therefore be considered to recommend a minimum limit to trickling, e.g. not less than 10-15 1 daily amounts per dripper.

Another problem concernes the role of root adaptation. It has often been stressed that intensification of rooting in the moistened soil highly improves the uptake of water. But then, the extent to which the intensification takes place is an important factor as well. Continuous fluctuations in daily application rates, and long interruptions of watering may prevent optimum adaptation of the root system and lead to inefficient water uptake in periods of high demand. For instance, a sudden increase in application rate in an extremely dry period following a period of dripping at low rates, or no dripping at all, may be less effective because of a relative low concentration of active roots in the large wetted soil volume. On the other hand, decreasing the application rate, or terminating irrigation after a period of intensive dripping may result in relatively high negative moisture potentials in a large volume of densely rooted previously moistened soil as will be shown below.

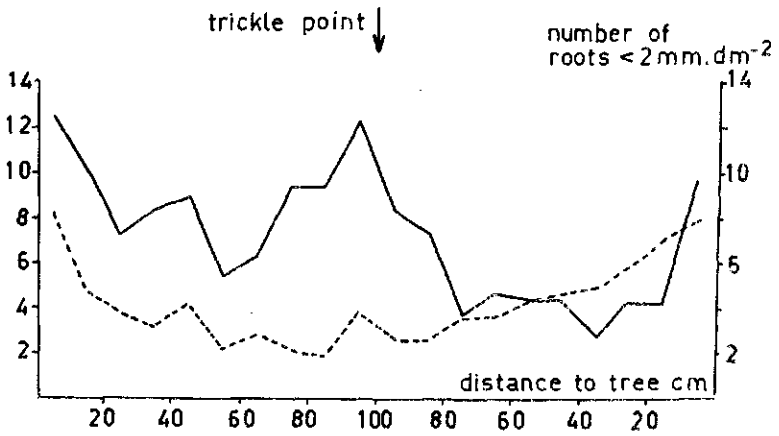

Fig. 2. – Effect of drip irrigation upon average root concentration (0-60 cm deep) of six-year old Cox's Orange Pippin apple trees. Dripping rate in 1975: 123 days × 16 $l.d^{-1}$, in 1976: 147 days × 14 $l.d^{-1}$. Root countings on vertical profile walls were done in april 1977. Dripping: ——, without dripping: -----. Experiment on shallow silt loam, Wilhelminadorp.

In order to investigate the influence of dripping, several root countings have been carried out on vertical profile walls in-between two trees. The first example represented in figure 2, shown the effect of two years of long-continued dripping at rather high rates. The graphs represent average concentrations in three profile walls only. Although irregular, the effect of dripping is very obvious. Root concentrations near the trickle point have at least doubled.

The second example, figure 3, refers to an experiment in which trickle irrigation was applied during four years, of which only 1976 was extremely

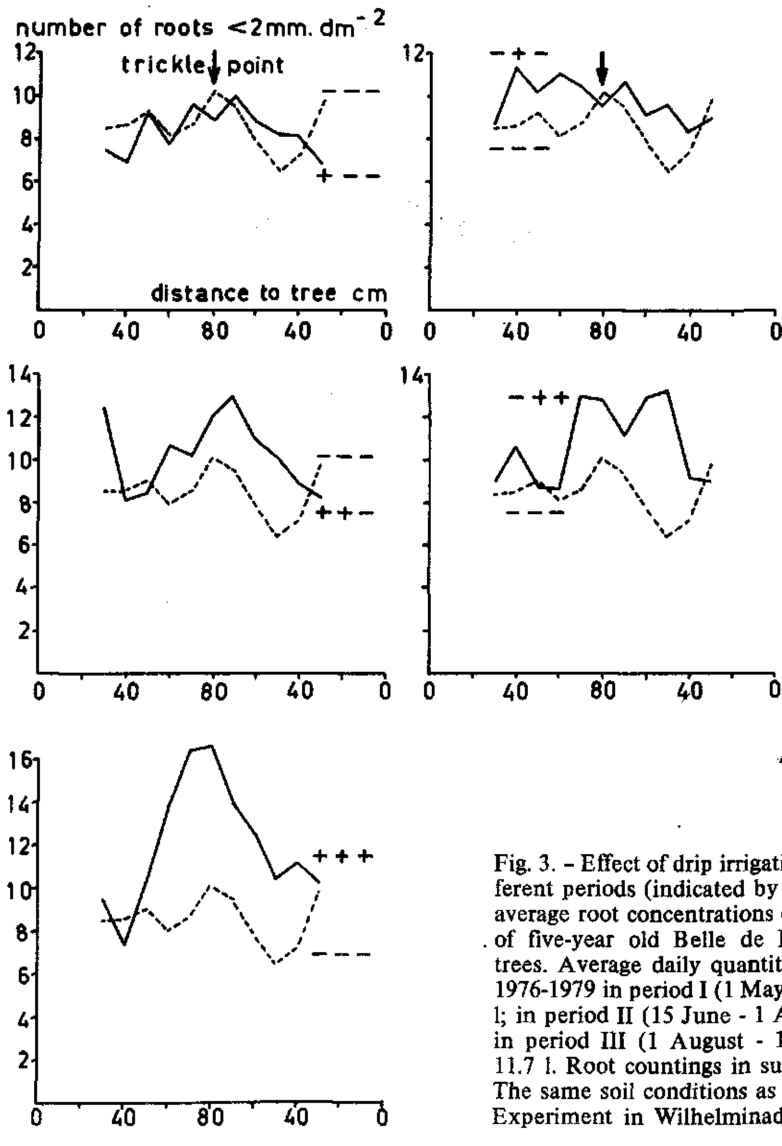

Fig. 3. – Effect of drip irrigation in three different periods (indicated by + signs), upon average root concentrations (0-60 cm deep) of five-year old Belle de Boskoop apple trees. Average daily quantities of water in 1976-1979 in period I (1 May - 15 June): 2.4 l; in period II (15 June - 1 August): 13.0 l; in period III (1 August - 15 September): 11.7 l. Root countings in summer of 1979. The same soil conditions as in fig. 1 and 2. Experiment in Wilhelminadorp.

dry. Dripping was done in various combinations of three successive short periods of 45 days each, with dripping indicated by + signs, without dripping with – signs. The data per treatment again represent averages of three separate profile walls.

Both examples clearly show the response of the root system to dripping: the increase in root intensity in the moistened soil more or less reflects the trickling rate that has already been applied in the past. Since the effect of trickling in dry periods depends on the application rate as well as on the root concentration under the dripper it may be concluded that trickling will be more effective the more water has been given in the past. This again seems an argument to recommend a minimum limit to trickling rates.

A final question to be raised refers to moisture tensions in and outside trickled spots. In periods of evapotranspiration in excess of precipitation, the densely rooted soil under the dripper compared with less densely rooted, untrickled soil at the same location tends to dry up more quickly as soon as dripping for whatever reason is terminated (figure 4). Irregular dripping, controlled by weather conditions will therefore sometimes result in situations in which the trickled part of the roots is subject to higher moiture tensions compared with the rest of the root system. Although the matter seems of sheer academic interest the question may be raised whether this could have a negative effect upon the total moiture supply of the tree. In other words, whether positive effects of dripping could be counteracted by high moisture tensions in the trickled soil during part of the sea-

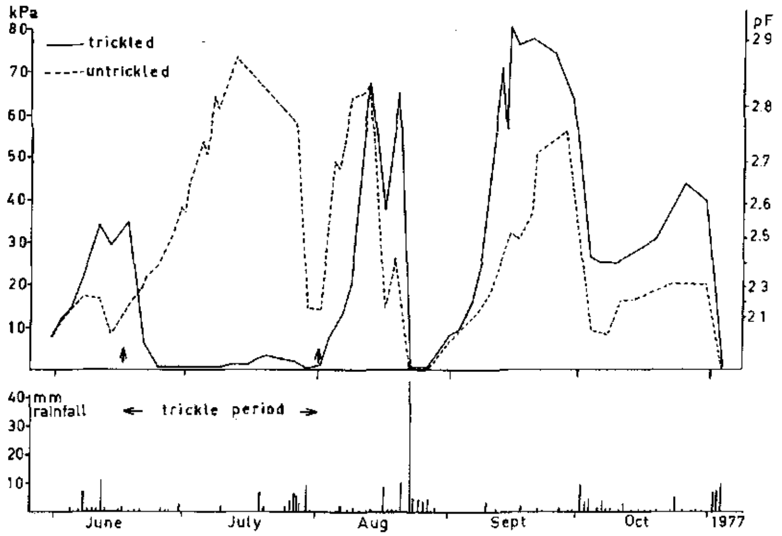

Fig. 4. - Tensiometer readings for trickled and control spots in-between apple trees. Location of all tensiometers (three per treatment): 0.25 m deep and 0.20 m beside the dripper. Dripping was confined to period II (15 June - 1 August, cf. fig. 3).

son in which the trickle system is not in action. Of course the matter could be far more important under arid conditions but there trickling is done uninterruptedly during the growing season.

Putting all the available data and considerations together it seems that correct trickling in a temperate zone under whimsical weather conditions is not simply a matter of turning the trickle tap on and off according to weather changes. Control by tensiometers raises the questions where to place them, how many and whether they can be handled by growers. Control by weekly balancing evapotranspiration and precipitation, setting aside the problem how to choose correct parameters, may result in the kind of situations that have been discussed above. For instance, the method of replenishing in the week to come, quantities of water lost in the preceding week, follows the demand for water far too slowly. Several tensiometer observations have shown that soil wetted by trickling, after turning the trickle tap off, may dry up to critical tensions within two or three days. Much research in the field of operating trickle systems correctly still seems necessary.

SUMMARY. – Drip irrigation in fruit growing in the Netherlands is still new, and growers experience and indications from research, how to apply the system are limited. In many cases it seems doubtful whether watering will pay but much depends on the soil conditions, how and when dripping is applied and in which quantities of water. Precipitation and evaporation in spring and summer are variable and since weather data are being used to assess the need for water it is obvious that dripping is being irregularly applied, with interruptions and in daily quantities varying from 0 to approx. 4 mm. The discussion is focussed on the question whether this could lead to inefficient uptake of water. Some background information on trickle irrigation in the Netherlands is given and proviional data from field experiments and root studies are presented.

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