

TRICKLE IRRIGATION IN A HUMID CLIMATE

Piet Delver
Institute for Soil Fertility, Haren (Gr.)
stationed at the
Research Station for Fruit Growing
Wilhelminadorp (Z.)
The Netherlands

Introduction

Favourable soil moisture and climatic conditions in the Netherlands suggest that, in general, irrigation of orchards could hardly be expected to significantly improve productivity. Yet, the practice of drip irrigation has rapidly expanded in the past eight years and has shown good or even excellent results. The first trickle system in a commercial orchard was installed in 1974; at present some 550 ha, i.e. 2.3% of the total orchard area, are irrigated in this way. A further increase, not only on droughty soils, is expected.

Where sufficient fresh water is available and the risk of spring frost is relatively high, preference is given to overhead sprinkling. However, years with considerable losses in yield and revenue due to frost are rare. For instance, 1981 with a 42% lower yield compared with 1980 was a boom year to most of our growers, except the few who lost almost all their crop. This generally high income was due to exceptionally high prices. In most cases the choice falls on trickle irrigation. This particularly applies to areas where fresh water is scarce and spring frost risk is low, like in the southwestern part of the country.

Some factors that contributed to the rapid expansion of trickle irrigation are more or less typical of Dutch conditions, e.g.

- a. The short economical life span (15-20 years) of the modern apple orchard with almost exclusive use of M.9 for rootstock, and the impossibility of moving to new land, necessitate rather frequent grubbing and replanting apple on the same sites. In most cases stunted growth caused by replant disease is to be expected. Trickle irrigation has proved an excellent means of eliminating the adverse effect of replant disease, especially in combination with potting compost added to the plant hole.
- b. High plant densities of 2000-2500 trees per ha, often more, render soils more droughty than under the former conditions of much lower tree numbers.
- c. Large-scale use of grass strips also enhances the need for irrigation. Dripping can then be water-saving compared with overhead sprinkling.
- d. Limited availability of fresh water. In the southwest even the suitability of slightly saline water for irrigation is of current interest.
- e. Under the prevailing European marketing regulations there is an almost inordinately strong influence of quality (grading, soundness) on fruit prices. In good cropping years a 10% yield increase due to better fruit growth can therefore easily result in a 20% higher financial profit. In heavily bearing, dense plantings drip irrigation can be a powerful means to improve fruit quality by bigger fruit size.

In newly planted orchards where dripping is practised to allow the trees to fill their allotted space more rapidly, profitableness of an investment for trickle irrigation is beyond dispute. Whether dripping will pay when started in an already mature orchard is sometimes questionable, particularly on good soils. Much then depends on soil conditions, occurrence of dry years, tree vigour, production level, fruit price and efficiency of dripping. On the last-mentioned aspects a comprehensive research programme is being carried out.

Soil Conditions

Most soils contain clay but, on average, river clay is somewhat heavier than sea clay. In many cases clay content decreases with depth. Water holding capacity and capillary rise of ground water into to root zone are the main factors that determine soil quality. Rooting depth in most orchards ranges from 50 to 120 cm, and available moisture (between field capacity and permanent wilting point) from 70 to 200 mm. Amongst droughty soils two main groups prevail.

In the southwestern province Zeeland, the first group of soils consists of a shallow, 30-80 cm deep light clay layer with a sharp transition to a compact sandy subsoil which tree roots do not penetrate. They are former sandbanks on which clay was deposited. These soils were reclaimed between seven and two centuries ago. Their dry character is due to limited water holding capacity (70-120 mm available moisture), too deep a ground-water level, and limited capillary rise. Figure 1 gives an example of water table depth and rainfall at the Research Station with such a soil, in an extremely wet (1974) and a dry year (1976). Such soil conditions also occur on pleistocene sand in other provinces, where rooting depth is confined to the shallow dark-brown topsoil containing organic matter. In the river clay area coarse sandy subsoil (former river beds) may give rise to drought.

The second group of droughty soils is characterised by a high clay content throughout the profile, sometimes of poor structure. Influx of water to the roots is slow and warm weather and high evaporative demand, rather than a low water holding capacity or deep water table, are the main conditions that determine the need for irrigation. Several of these soils occur in the river clay area.

Climate

An outline has been given in my first talk. The data for 1974 and 1976 give a somewhat exaggerated impression, but irregular distribution of rainfall and varying temperatures are certainly typical of the Dutch summer. They may affect flower initiation and fruit quality factors such as skin russeting, cracking, colouring and keepability. In summer, daily maximum temperatures may vary between 15° and 30°C. Evaporation calculated according to the Penman formula for the period April-August, in excess of rainfall averages 223 mm, but may range from 0 to 350 mm; 1976 was exceptional with 450 mm in the south-west. The alternation of weather types gives rise to problems concerning start, continuity and intensity of dripping.

Water Resources

On 85% of the fruit area under trickle irrigation, well water is withdrawn from 6-60 mm depth. It contains iron, 3-15 mg Fe per litre or more, so sometimes the water has to be aerated, filtered through a gravel bed or stored in a basin to allow the iron to precipitate. With the currently used 4 l per hr drippers, iron contents up to 6 mg Fe cause little trouble due to outlet clogging, provided the drippers are treated with nitric acid when necessary.

In the southwestern province of Zeeland most of the land is surrounded by sea-inlets. Open water in canals and ditches contains several grams of salt per litre, so fresh water is scarce. This is demonstrated by the fact that in the dry year 1976 on average 12% of all the cultivated land in Holland could be irrigated by overhead sprinkling, whereas in Zeeland it was only 0.3%. However, some water can be withdrawn from wells in the shallow fresh-water layer, approx. 2-10 m deep, that lies on top of the deeper saline groundwater. To avoid salinisation of the well by deep water, the withdrawal rate should be kept very low, about 50 m³ per day per well being the maximum. A good measure in this connection is to interconnect a few not too distant wells. Under these marginal conditions of water supply only trickle irrigation can be considered for watering and even then it should be used very efficiently.

Effects of Trickle Irrigation

Young orchards

By far the most significant and convincing results of drip irrigation have been achieved in newly planted apple orchards. Dry periods in spring and summer, on average occurring once every two years, affect initial growth, but far more frequent and serious is the effect of specific re-plant disease, particularly in combination with drought. Stunted growth results in delayed onset of bearing, but eventually also in failure of trees to adequately fill their space. Such orchards never reach the potential cropping level.

On sandy soils covering only 12% of the fruit area, use of nematocides for fumigation appears to be necessary, but on the remaining 88% of clay and loess soils, fumigation with f.i. chloropicrin is avoided. Reasons are the high costs, toxicity and, sometimes, the necessity of leaving the land lie fallow for one season. Moreover, potting compost added to the plant hole has given excellent results and is considered a cheap, effective substitute for fumigation. It is a mixture of white and black peat (the structure of the latter is improved by freezing), and some sand with addition of chalk and macro- and microelements. Potting compost should not be mixed with the original soil of the plant hole. It makes the plant more susceptible to drought because the roots tend to remain in the compost for some time. When watered it constitutes a water reservoir, therefore dripping combined with potting compost has given excellent results. Effects of re-plant disease can probably be expected in at least 85% of all new apple plantings.

Potting compost is widely used, and therefore prospects for a further expansion and profitable use of trickle irrigation, not only on droughty soils, are good. The following experiment will demonstrate this.

At the Research Station on apple orchard was grubbed in 1976 and re-planted in February 1977 with the new, promising cultivar Jonagold on M.9 in single rows 3.5 m apart and at 1.5 m within-row spacing (1800 trees per ha). All eight combinations of the following treatments were applied: a. Control; b. Drip irrigation near the stem, 10-20 l per tree per day in each of the years 1977-1981; c. Mushroom compost mulched around the stem. It is a waste product from mushroom cultivation and it limits soil moisture losses due to evaporation; d. Potting compost 20 l per plant hole. The soil is moderately droughty, but in the period 1977-1981 precipitation was almost normal.

Figure 2 shows the main effects as percent increase in total shoot production in comparison with the control. In the first years potting compost and dripping resulted in considerably better shoot growth, particularly when both treatments were combined. Because trees so treated grow rapidly, they fill their space sooner, therefore also experience between-tree competition for moisture, nutrients and light earlier than untreated trees. Consequently the effects of the treatments tend to fade out when compared with untreated, smaller trees. Moreover, potting compost and mulch had only a temporary direct effect, mainly in the first year. Their after-effects partly result from the flush of growth in the first year. Dripping had a more lasting effect because it was repeated annually.

Main effects on yield in Figure 3 also show marked relative increments. Addition of water tended to enhance the effect of potting compost. Experience of growers seems to confirm this. Table 1 shows the actual production over 1978-1981 and, in Table 2, the gross profit obtained due to dripping, or potting compost, and the two treatments combined, was calculated on the basis of an average market price for apples over the last few years (1981 with exceptionally high prices excluded; high prices for Jonagold also excluded).

Current investment costs of a trickle installation, excluding the costs of drilling the well, are between approx. \$ 2200 and 3400 per ha; these costs were earned back after three crops or, when trickling was combined with compost in the plant hole, even after two crops. Such experimental results of course encourage growers to practise dripping in newly planted orchards, particularly because the results were obtained under average replant and weather conditions and similar effects were also achieved in experiments elsewhere. In one of these on heavy river clay, with the same amounts of water (160 mm in 1981), the effect of dripping on shoot growth in the first year was by far superior to that of overhead sprinkling.

In current experiments with young trees at the Research Station also the suitability of slightly saline water (1-3 g NaCl per litre) for dripping is investigated. A tentative impression is that although the effect on shoot growth is inferior to that of fresh water, slightly saline water may be used under dry soil conditions provided it is given without interruption

in small quantities (2-5 l per tree per day) and when the air temperature is only moderately high. It should be stopped only in very rainy periods.

Mature orchards

The model in Figure 4 demonstrates the expected after-effect of dripping during the juvenile phase on productivity. In wide-planted orchards (A), irrigated trees grow bigger and will better fill up the available space. This results in a more or less lasting higher productivity even when dripping is terminated when the trees have reached maturity. For a given scion-rootstock combination, potential productivity level for good-quality fruit is mainly determined by climate and soil. Because in the wide planting this maximum possible level is not nearly reached, fruit size in general is satisfactory and the risk of too many small fruits in dry years is limited. In dense, or rather ultra-dense plantings (C), the lasting effect of bigger trees is less marked or insignificant. With 2000 or more trees per ha also non-irrigated trees fill the space and approach potential productivity although 1-2 years later than irrigated trees. Thus, the effect of dripping on tree size and production level is confined to the initial years, but in the mature orchard fruit size and quality are more critical. Drought sooner leads to poor quality, and dripping then is effective mainly through improved fruit size and quality. An example of the effect of plant density and drought (1976) is given in Table 3. The Boskoop variety is, by nature, a large-size apple.

Field experiments and experiences of growers in mature orchards have indeed confirmed the above effects from trickling, but usually they are small compared with effects on growth in initial years. Under normal soil and weather conditions, increases in fruit weight vary from negligible to only a few per cent, whereas marked effects of, say, 10 to at most 30% higher fruit weight appear only in exceptionally dry years or on dry soils. Nevertheless, financial returns of dripping in close plantings often exceed expectations because of the positive effect of improved quality (better coloured, larger, less russeted, fewer cracked fruits) on fruit price.

According to calculations carried out by the Agricultural Economic Research Institute based on total annual costs of trickle installations (running from \$ 350 to 450 per ha per year), minimum financial returns required for profitableness amount to between 4% and 12% extra income depending on productivity level, fruit price, and annual costs (depreciation, operating expenses). When irrigation is practiced right from planting, these requirements are easily met, but when it is started for the first time in mature orchards on good soil, with moderate productivity and less valuable cultivars and maybe a series of normal rainfall years to come, it is doubtful that dripping will pay. Much therefore depends on efficient use of the installation. Factors such as number and position of drippers, starting time, continuity, quantity and distribution of water become important. Current research at the Research Station in Wilhelminadorp is predominantly devoted to questions of efficient dripping. A few examples will be given.

Efficient Watering

When to start dripping?

Results of efforts to determine the moment of first need for watering on the basis of a moisture balance sheet, although essentially workable, so far have been unsatisfactory. This balance is based on data on evaporation, capillary rise of groundwater, rainfall, water holding capacity of the soil and orchard factors. Too many assumptions and unknown factors are involved. Growers find the procedure too complicated. There is a growing interest, however, in the use of tensiometers. Therefore, research on the relationship between crop response to irrigation and moisture level of the root zone as indicated by tensiometers, is given much attention. Shoot growth seems to respond more critically to drought than fruit growth. Particularly in the case of newly planted and young trees in the first two years, it is recommended to start irrigation as soon as a few dry days have passed and midday temperatures exceed 20°C, even when the deeper soil still appears to contain adequate moisture. A late start of dripping should be avoided because it may result in undesirable regrowth of shoots that are susceptible to mildew later in the season.

In mature orchards on most soils with a subsoil of light clay or sand, capillary supply of water to the deeper roots is a major factor that has to be taken into account. By frequently measuring diameters of Cox's Orange Pippin fruits during the growing season, on control plots as well as on trickle-irrigated plots, it was established that fruits start to respond to irrigation only, when tensiometer readings at 40 cm depth exceed 16 cbar, i.e. pF 2.2 (rooting depth approx. 50 cm. Moisture tension at this depth is an indication of capillary water supply to the deeper roots and is closely related to ground water depth. Once this relationship is known, the grower can use water table depth, along with rainfall data, as a useful guide for watering. Figure 5 demonstrates the drying-up of the silt loam soil in this experiment in 1980, in a period with very little rain and a water table dropping from 112 to 135 cm below the surface. The subsoil below 60 cm is a medium loamy sand. Irrigation started on 12 May, but fruit growth did not begin to respond until approx. 10 June under average maximum temperatures of 24°C. Under these conditions 125 cm below the surface was a critical water level.

Another factor that markedly influenced fruit growth response to dripping was daily maximum temperature, which is correlated with evaporative demand. In dry periods with maximum temperatures of approx. 17°C there was no response to amount of water given (variation 0-20 l per tree per day), but at 22°C there was a positive response: the lead in fruit growth on irrigated plots increased significantly as more water was given.

An observation worth mentioning is the response of trees to interruption of dripping in dry periods or in periods with only little rain. Trees that are regularly drip-irrigated develop considerably more roots in the moistened soil than elsewhere. When dripping is stopped for some time, moisture tensions in the trickled spot rise more rapidly than elsewhere in

the root zone. We observed that when this interruption is done in warm weather, daily increment of fruit diameter drops below that of non-irrigated trees.

Moistened Volume-Water losses

When plant densities are high, about 2000 or more trees per ha, many growers consider economizing on investment costs by limiting the number of drippers to one per two or even three trees. Two problems then arise:

- a. With low numbers of, say, less than 1500 per ha, and daily discharges based on calculations using orchard factors and evaporation (variation 0-40 l per day per dripper), will the moistened volume of soil be adequate to allow efficient water absorption by the roots?
- b. Will high discharge rates give great water losses due to percolation to the subsoil?

Because in Holland dry conditions usually mean shallow-rooted soil, we unfortunately have to answer these questions with no and yes, respectively.

We tried to learn something about this by inserting a total of 80 tensiometers at 10, 25, 40 and 60 cm depth, and at distances of 20, 30, 40, 50 and 60 cm from trickle points in the row, centered between apple trees. The root zone was confined to the 50 cm silt loam layer, the subsoil was loamy sand. By varying output rates within a short period and reading the tensiometers after a fixed number of hours we were able to draw up moisture profiles as shown in Figure 6. As was confirmed by other, similar evidence, total volume of moistened soil (tension boundary $pF = 2.2$) did not significantly increase with daily amounts of more than 10 l, and the calculated maximum volume of moistened soil to a depth of 60 cm approached 500 l per trickle point. However, at the same time the diameter of the very wet zone under the trickler ($pF < 1.8$) markedly increased. As this zone merges into the capillary zone, increasing daily output rates will soon result in increasing water losses by seepage. This was confirmed by the fact that water tables rose in periods of intensive watering. An even distribution of watering over the day may limit these losses.

According to an Israeli view, for optimum efficiency of water absorption, moistened volumes in a humid climate should be in the range of 20-30% of the total soil volume occupied by roots. In our experiments, with 1000 drippers per ha the moistened volume would constitute only 9-11%, and with 2000 drippers 18-22%, at best. It therefore seems that we have to advise strongly against economising on numbers of drippers.

Prospects

It is the task of current research to show how optimum results can be obtained with a minimum of water. To achieve this, the fruit grower of tomorrow will have to eliminate guess-work as much as possible. Probably he will need small meteorological equipment, a computer and a good computer programme; some growers already are so equipped. His programme has to include a large number of variables such as evaporation, effective rainfall, information on crop (age, plant density, leaf area, yield level) and on soil

and groundwater influences. Good irrigation is then merely a matter of correct evaluation of these variables.

Table 1. Effect of drip irrigation and potting compost added to the plant hole, on yield of Jonagold apples on M.9, planted in 1977 (1800 trees per ha).

Treatment	Yield x 1000 kg per ha				
	1978	1979	1980	1981	'78-'81
Control	5.6	14.6	17.8	41.7	79.6
Drip irrigation	8.1	17.8	22.7	44.5	93.1
Potting compost	8.4	16.7	20.3	42.3	87.6
Potting c. + dr. irr.	11.3	22.8	28.4	47.5	110.0

Table 2. Gross profit in 1978-1981 obtained for Jonagold apples by using drip irrigation and potting compost, assuming an average price of \$ 0,30 per kg (actual average price for Jonagold approx. \$ 0,64 per kg).

Treatment	US \$ per ha (1\$ = f 2,50)				
	1978	1979	1980	1981	'78-'81
Drip irrigation	756	972	1458	838	4024
Potting compost	837	621	729	187	2374
Potting c. + dr. irr.	1728	2457	3186	1748	9119

Table 3. Effect of plant density on fruit weight in three single-row and one bed systems, in good cropping years. Belle de Boskoop apple trees, planted in 1972.

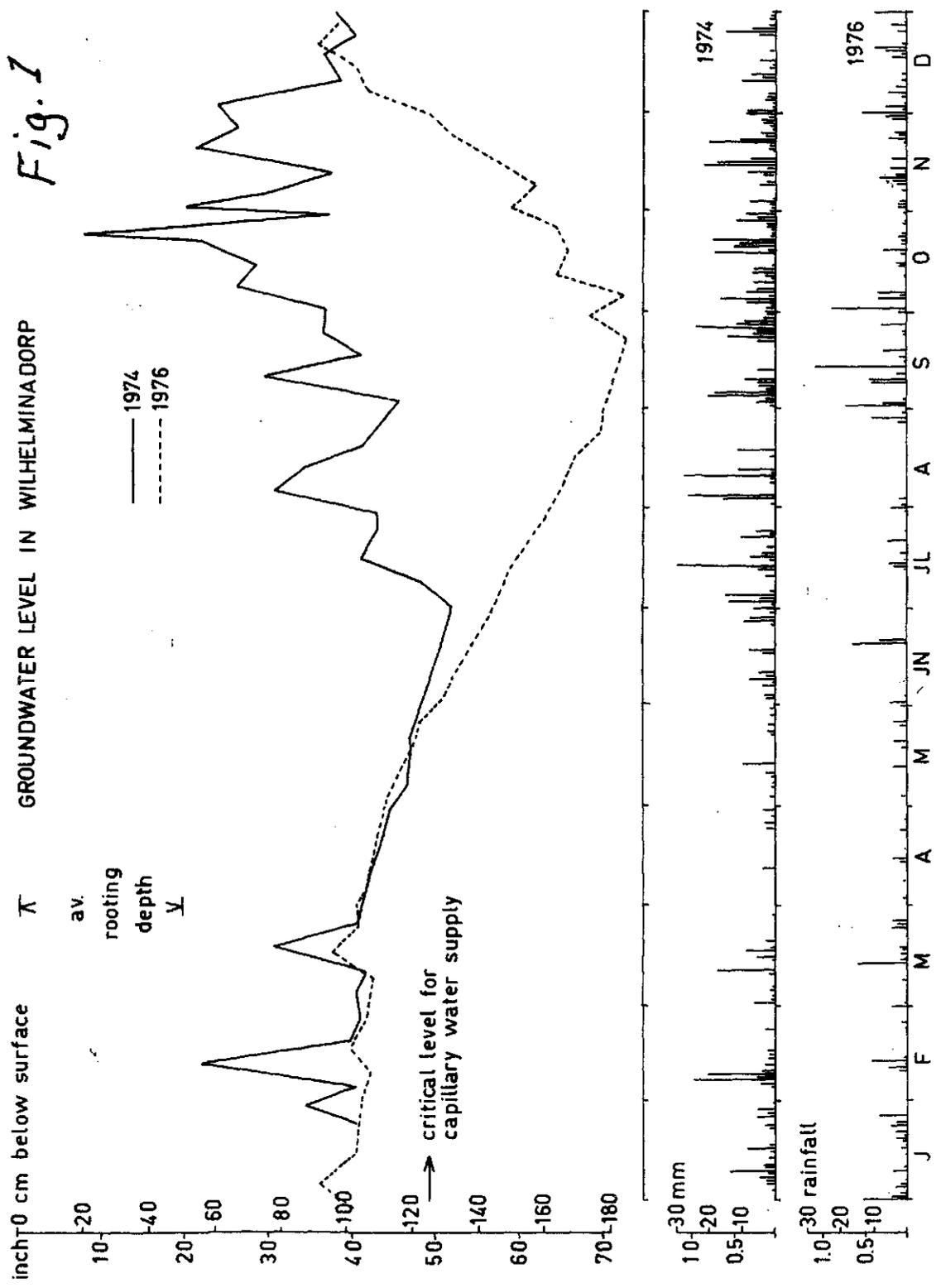
Tree spacing cm	Trees/ha	Fruit weight g			
		1975	1976	1978	1980
395x205	1110	226	143	193	194
336x136	1860	206	133	185	185
300x102	2930	203	120	170	179
bed	3330	202	113	168	154

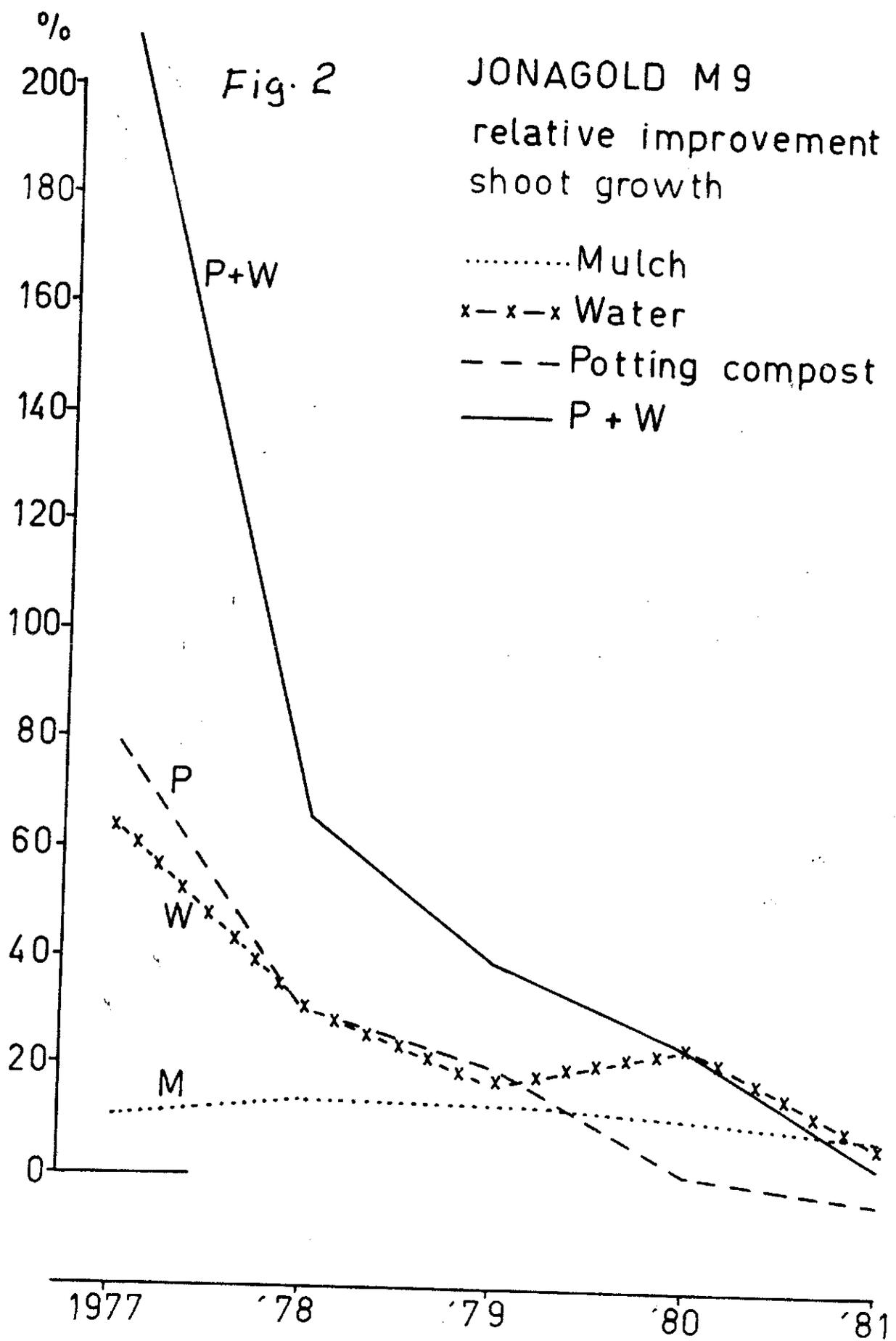
Legend to figures

- Figure 1. Water table depth in a reclaimed marine clay soil at Wilhelminadorp Research Station, and rainfall distribution in two extreme years.
- Figure 2. Shoot growth increments of Jonagold apple trees planted in 1977, as a percentage of shoot length of untreated trees.
- Figure 3. As figure 2, for fruit production.
- Figure 4. Simplified model of onset and continuation of production as influenced by age and early-applied irrigation. A: for a widely planted apple orchard on vigorous rootstock. B and C: for a high-density and an ultra-high density orchard on M.9, respectively.
- Figure 5. Drying of a silt loam soil in spring between two trees monitored by tensiometers. Moisture profiles in the tree row, trees at 80 cm from the middle. Water table depth 112, 123 and 135 cm, respectively.
- Figure 6. Moisture profiles in the same silt loam soil as figure 5 derived from tensiometer readings, as influenced by emitter discharge. Readings 20 hrs after dripping.

Fig. 1

GROUNDWATER LEVEL IN WILHELMINADORP





JONAGOLD M 9

relative improvement
yield

.....Mulch

x-x-xWater

--- Potting compost

— P + W

