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COMPARISON OF METHODS OF WATER SUPPLY TO HOTHOUSE TOMATOES

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Abstract. - For water application to hothouse tomatoes, a sprinkling method with which the entire soil surface is wetted has been used in The Netherlands for many years. For a few years, however, some other methods of water supply are coming into use, methods with which the water is applied in spots or strips. In the use of spot- or strip-watering, work can be carried out in the crop at any moment because the crop and the picking paths remain dry.

At the Research Station at Naaldwijk, some watering methods were compared with each other in experiments with hothouse tomatoes. In these experiments, the usual sprinkling method gave less satisfaction than methods of spot- and strip-watering. It is likely that the water supply to the crop was more regular in the last-mentioned methods. The water was applied frequently and was brought close to the roots with these methods.

Introduction. - For water application to hothouse tomatoes, a sprinkling method with which the entire soil surface is wetted has been used in The Netherlands for many years. For a few years, however, some other methods of water supply are coming into use, methods with which the water is applied in spots at the foot of the tomato plants or in strips between two plant rows. In spot-watering, the soil surface remains dry almost entirely. In strip-watering, it remains dry in the picking paths.

The use of spot- and strip-watering is not all new in The Netherlands. Thus, a spot-watering system was tried fifteen years ago, viz. the Cameron trickle-irrigation system of the time. The tomato yields obtained by means of this irrigation system were very satisfactory. However, the trickle nozzles clogged regular which was promoted by the use of surface water contaminated with organic matter. As a result, the trickle-irrigation system mentioned was unsuccessful in practice.

Almost simultaneously with this system, a strip-watering system was introduced, viz. a system with lay-flat tubes. These tubes were used on a very small scale from that time. Due to lack of experience, the results obtained with them were generally not satisfactory.

At present, the growers are working on other lines than a number of years ago. They are purposefully looking out for irrigation methods with which tomato plants grow well continuously and with which the crop and the picking paths remain dry which has the advantage that work can be carried out in the crop at any moment. Consequently, the interest in spot- and strip-watering has increased sharply. In the main, two systems of spot-watering and two systems of strip-watering are tried. These systems and the usual sprinkling system will be briefly described in the following paragraphs.

Usual sprinkling. In usual sprinkling, there is one sprinkling line per greenhouse span of 3.20 m, the nozzles being spaced at intervals of 1.5 m. At first, the lines lie over the crop. Later on, when some leaves have been removed, the lines are usually brought down to a height of 20-30 cm above the soil surface. In both line positions, the entire soil surface is wetted. The sprinkling intensity averages about 60 mm per hour.

Strip sprinkling. In strip sprinkling, there is one sprinkling line per two rows of tomato plants, the nozzles being spaced at intervals of 75 cm. The lines lie upon the soil from the beginning of the growing season. The water pressure in the lines is adjusted in such a way that the sprinkling water reaches the foot of the plants but the picking paths remain dry. The sprinkling intensity amounts to about 75 mm per hour (calculated over the entire soil surface).

Irrigation by means of lay-flat tubes. The lay-flat tubes consist of a thin layer of polyethylene. They have a diameter of 4 cm during irrigation and lie flat upon the soil between the irrigation turns. There are little holes in both edges of the tubes at intervals of 15-29 cm. There is one tube per two rows of tomato plants. In consequence of the practice to cover the lay-flat tubes with plastic sheets or to place them in little gullies, the irrigation water usually does not reach the foot of the plants. The irrigation intensity amounts to about 50 mm per hour.

The described system of lay-flat tubes is rather fragile and its water distribution is not always equally fair. However, it is rather well usable if new tubes are employed every year.

Trickle irrigation. The trickle-irrigation system used most at present is the Volmatic system with which every tomato plant is supplied slowly with water by means of a little tube. The output of a little tube averages about 0.8 litre per hour which corresponds with an irrigation intensity of 2 mm per hour.

The Volmatic trickle-irrigation system gives somewhat more satisfaction than the Cameron system mentioned before but the utilization of the Volmatic system is hindered by clogging as well. I cannot yet judge about the new Cameron system which is brought out recently. It was not used in The Netherlands up to now.

Irrigation by means of perforated pipes. The perforated pipes consist of rigid p.v.c. and have an inner diameter of at least 14 mm. The pipes lie upon the soil, one pipe along every row of tomato plants. Close to every plant, there is a little hole in the underside of the pipes. The output of a little hole amounts to about 0.4 litre per minute (corresponding with an irrigation intensity of 60 mm per hour), so per irrigation spot a rather large quantity in a short time. This is a disadvantage when the irrigation water has a low temperature as the temperature of the roots close to the irrigation spots will be lowered rather strongly in this case.

A higher watering frequency is needed in spot- and strip-watering than in usual sprinkling. In practice, water is applied 2-3 times a week in usual sprinkling, once a day in strip-watering, and 1-2 times a day in spot-watering.

At the Research Station at Naaldwijk, the watering systems discussed were compared with each other in three experiments with hothouse to-

matoes. The watering frequencies employed in the experiments were more or less equal to those mentioned before.

Methods. - The experiments were housed in a Venlo block with heavy pipe heating. The soil type in the greenhouse was a loamy sand containing 5% organic matter, 1% $CaCO_3$, and 15% clay (particles < 16 mu). The pH of the soil was 6.7. The base dressings were founded on the results of soil testing. The tomato variety used was Extase.

The quantity of water which had to be applied was estimated from the radiation intensity. In the first two experiments, the estimation rested mainly on experience. In the last experiment, however, it was based on the graph which was found by De Graaf (see: Van der Post et al., 1972) for the relationship between radiation intensity and transpiration.

Compound fertilizer was added to all the irrigation water. The addition was done by means of a diluter with an electrical concentration indicator (Sonneveld and Van den Ende, 1967). The electrical conductivity of the mixture served as the basis for monitoring the concentration which was indicated in atmospheres of osmotic pressure. For the fertilizers used, one atmosphere corresponded with 2-3 gr per litre. In the beginning of the experiments, a fertilizer concentration of about 1 atmosphere was kept on for a short time. Then, the concentration was lowered gradually to about 1/4 atmosphere. This concentration was maintained from about two months after planting out till the end of the experiments.

The experiments were carried out in 1970, 1971, and 1972. The growing season ran from the beginning of July till the middle of November in the first experiment and from the middle of January till the middle of August in the second and third experiments.

In the first experiment, a comparison was made between usual sprinkling, strip-sprinkling, and trickle irrigation. In contrast with practice, the lines of the usual sprinkling system were lying over the crop continuously. Further, sprinkling by means of the strip-sprinkling system was done twice a week, so less frequently than after the usage of the present day. The trickle-irrigation system used was the Volmatic system.

In the second experiment, the same watering systems were compared again with each other. In contrast with the first experiment, however, sprinkling by means of the strip-sprinkling system was done now daily. In addition to the watering treatments, another treatment was included in the second experiment. In this treatment, the tomato plants were grown in plastic pots and irrigated by means of trickle irrigation in the pots. The pots had a diameter of 14 cm and were set out upon sheets of white polyethylene. The sheets which were present only in the treatment with pots covered the soil surface between the picking paths. They were removed from under the pots at the flowering of the third truss. As there were holes in the bottom of the pots, the roots in this treatment were penetrating the greenhouse-border soil from that time.

The third experiment was a factorial experiment with 4 watering methods, 2 quantities of water, 2 fertilizer concentrations, and 2 methods of growing, viz. growing with and without pots. The watering methods

were strip sprinkling, irrigation by means of lay-flat tubes, trickle irrigation, and irrigation by means of perforated pipes. So, the usual sprinkling method was not included in this experiment. The lay-flat tubes were placed in little gullies. Water was applied 1 - 2 times a day in all the treatments. The water quantities were a normal quantity which was determined by means of the above-mentioned graph and 1.5 times the normal quantity. The fertilizer concentrations in the irrigation water were a normal concentration as described before and 2 times the normal concentration. The treatments which received the larger quantity of water received proportionately more fertilizer as well. The pots were set out upon the greenhouse border. Polyethylene sheets were not used this time. In all the treatments, therefore, the roots were penetrating the border soil from the beginning of the experiment. In the treatments with pots and irrigated by means of perforated pipes or trickle tubes, irrigation was done in the pots.

Soil samples were taken from the 0 - 25 cm layer several times during the growing seasons. In the treatments with spot- or strip-watering, two soil amples were taken at the same time, one sample from wet parts of the soil and one sample from dry parts. The soil samples were dried and then extracted with water in a soil: water ratio of 1 : 5 (Van den Ende, 1968). The nitrogen-, potassium-, magnesium-, and phosphate contents of the extracts were determined and expressed in milligrams N, K_2O, and MgO, and P_2O_5 per 100 grams of dry soil.

Results. - In the wet parts of the soil, the nitrogen-, potassium-, and magnesium levels generally decreased regular during the growing season. In the dry parts, on the contrary, they increased. The phosphate levels were rather constant. However, they were higher in the wet parts of the soil than in the dry parts (Van den Ende, 1952). The nitrogen-, potassium-, and magnesium levels found in treatments irrigated by means of perforated pipes are listed in Table 1. The phosphate levels found in these treatments averaged about 6 for the wet parts of the soil and about 4 for the dry parts.

The total quantity of water which was applied amounted to about 250 mm in the first experiment and to about 620 mm in the second experiment. In the third experiment, the normal quantity of water came to a total of 530 mm and the larger quantity to a total of 795 mm.

In the beginning of the first two experiments, somewhat more water was given in the sprinkling treatments than in the trickle-irrigation treatments. The reason of this lay in the fact that the root systems were still small at that time. In the trickle-irrigation treatments, the tomato plants had the disposal of almost all the irrigation water from the beginning as the water was applied close to the root systems. This was not the case in the sprinkling treatments. Here at first, a great part of the irrigation water wetted soil in which roots were not present yet. This disadvantage was met by giving somewhat extra water in the sprinkling treatments in the beginning. This extra water was applied mainly by means of the sprinkling systems. The first ten days, however, some of it was applied by hand at the foot of the tomato plants.

In the third experiment, the watering systems of the experimental

design were not used for the first twenty days. Watering was done entirely by hand during this time. The need of this measure differed for some groups of treatments. The measure was superfluous for the treatments with trickle irrigation or irrigation by means of perforated pipes and it was favourable for the treatments with strip sprinkling or irrigation by means of lay-flat tubes. It was favourable especially for those of the latter treatments in which the tomato plants were grown in pots as the water which was applied by means of the strip-sprinkling system or the irrigation system with lay-flat tubes did not reach the soil in the pots. After the period of the first twenty days, watering by hand was stopped and watering according to the experimental design was started. This did not bring about any problem. The root systems were already rather well developed at that time.

Some important yield data of the experiments are given in Table 2. In 1970, there was not a statistically significant difference between the yield of the treatment with strip sprinkling and that of the treatment with trickle irrigation. These two yields were significantly higher than the yield of the treatment with usual sprinkling. It is likely that the cause of this difference in yield lay in the beginning of the experiment. At that time, the plants were smaller in the treatment with usual sprinkling than in the treatments with strip sprinkling or trickle irrigation. The most plausible explanation for this difference in plant size and for the difference in yield is that the initial water supply to the roots in the first-mentioned treatment was not sufficient. However, the regular wetting of the leaves in this treatment, a result of the overhead sprinkling, may have had also some effect.

In 1971, the highest yield was obtained with the treatment in which the plants were grown in pots and were irrigated by means of trickle irrigation. This yield amounted to 17. 6 kg per square metre. The yields of the other treatments of 1971 are given in Table 2. All the yield differences in this year were statistically significant. Like in 1970, the cause of these differences lay probably in the beginning of the experiment. At that time, the size of the plants increased in the order usual sprinkling, strip sprinkling, trickle irrigation, and trickle irrigation in pots. In 1971, unlike in 1970, the yield of the treatment with strip sprinkling was lower than that of the treatment with trickle irrigation. It is likely that this difference in yield has been promoted by the fact that the soil was rather dry at first. Especially under this circumstance, watering at the foot of the plants may have been very favourable. In the treatment with trickle irrigation in pots, there was probably altogether not any loss of irrigation water in the beginning of the experiment. This is a possible explanation for the fact that this treatment had the highest yield. However, the use of the pots had also some other consequences for the roots, like a comparatively high temperature of the soil in the pots and not any root damage consequent on the setting out of the plants. Further, the reflection of light by the white polyethylene sheets used in the treatment with pots may have had also some effect.

In 1972, there were not any statistically significant differences in yield between the watering methods, the yields being fairly high (Table 2).

In this year, there were also not any great differences in plant size in the beginning of the experiment. Due to the watering by hand, the plants in all the treatments were having a good water supply at their foot at that critical time. Among the other experimental factors, the fertilizer concentration only had a statistically significant effect. The yields of the treatments with the high fertilizer concentration were on the average 7% lower than those of the treatments with the normal concentration.

The fruit out of the experiments were generally goodlooking. In the last month of the third experiment, however, the fruit coloured partly unevenly at ripening. This uneven colouring was probably caused by high temperatures. The treatments did not affect it.

General comments. - Spot- and strip- watering cause an unequal distribution of nutrients in the soil. This is a disadvantage for a crop like lettuce which is often grown after tomatoes.

On dune-sand soils with low organic-matter content, the growers are not in want of spot- and strip-watering. The picking paths on this soil type always remain walkable and the usual sprinkling lines are brought down rather early.

On soils with a high clay content, spot-watering and irrigation by means of lay-flat tubes are often not useful owing to the slight horizontal spreading of the water. The soil parts which are not wetted dry up and deep cracks arise.

At present, usual sprinkling is still used most. Among the methods of spot- and strip-watering, strip-sprinkling and irrigation by means of perforated pipes are used, mainly irrigation by means of perforated pipes especially where the plants are grown in pots.

For strip-watering and also for usual sprinkling, further experiments are necessary in order to investigate thoroughly the need of watering by hand at the foot of the plants. The frequency of the watering turns needs to be studied as well.

Finally, growing in pots, with and without using polyethylene sheets, requires further studies too.

Table 1 - Average values of nitrogen-, potassium-, and magnesium contents of wet and dry parts of the soil in two treatments of the third experiment (treatments with: perforated pipes, normal water quantity, and normal fertilizer concentrations).

Dates	N		K_2O		MgO	
	wet	dry	wet	dry	wet	dry
10/4	8	9	15	18	8	15
16/5	4	13	12	21	6	23
3/7	4	16	9	29	6	31

Table 2 - Yields of tomatoes in the experiments.

Watering system	Yields in kg/m2		
	1970	1971	1972
usual sprinkling	7. 1	12. 8	
strip sprinkling	8. 5	14. 6	15. 3
trickle irrigation	8. 2	15. 9	15. 6
lay-flat tubes			15. 9
perforated pipes			15. 8

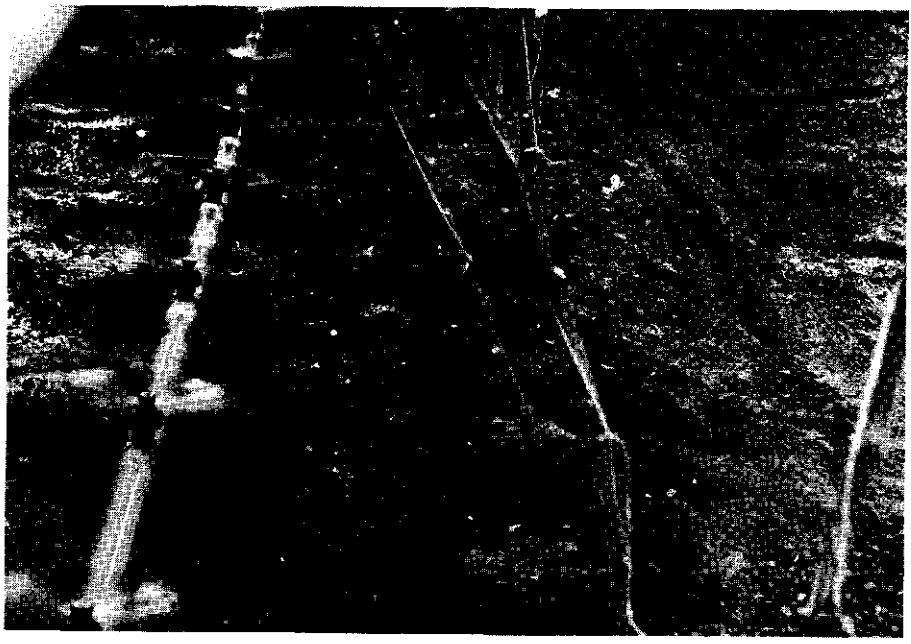

Figure 1 - Strip sprinkling.

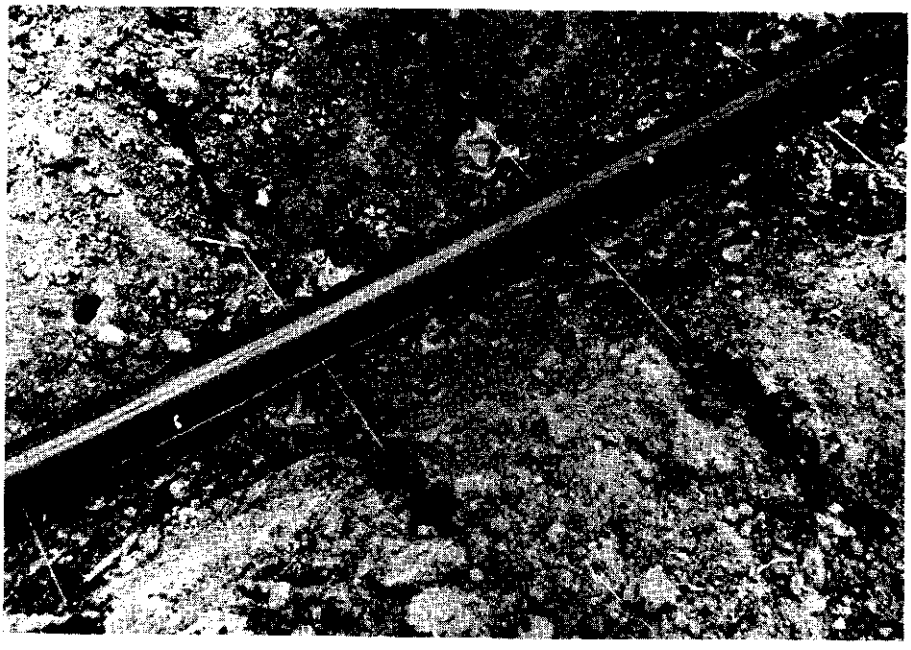

Figure 2 - Irrigation by means of lay-flat tubes.

Figure 3 - Trickle irrigation.

Figure 4 - Irrigation by means of perforated pipes.

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