System and Climate Related *Pythium* Problems in Mobile Chrysanthemum Growing Systems

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Abstract

One Dutch greenhouse company started to grow chrysanthemums in a mobile system. The system's basic unit is a sub-irrigated V-shaped gully of 8.0 m long and 5 cm wide, filled with a peat-coir mix. The system is hampered by growth differences along the length profile of the gullies and *Pythium* related yield reductions of up to 10% during the summer period. A series of experiments aimed to mimic the problems, explain causes and to advice on improvements.

A *Pythium ultimum* pathogen from the grower was cultured in the laboratory and disseminated in the irrigation water tanks. In part of the cultivations the plants were subjected to high temperature and low air humidity treatments aimed at creating stress and *Pythium* susceptibility. Various plugs fit for transporting rooted chrysanthemum cuttings were tested as well.

The results show that *Pythium ultimum* is initially the result of a too high water content in the first 10 days of the propagation phase. This was a direct consequence of precipitation of pure water by the mist system used to keep the relative humidity high. A related factor was a too low EC of <0.2 dS.m^{-1}. Both high water content and low EC were more severe towards the drain outlet. The climate experiments indicated that in chrysanthemum propagation low air humidity, high light levels and high temperatures are not as damaging as presumed and moderate levels of transpiration enhance growth.

In conclusion abandoning the mist system will increase root growth and above ground growth and decrease the incidence of stem rot and the chances of *Pythium* infection. Furthermore, techniques to monitor and maintain proper substrate water content and EC levels will prevent re-occurrence of these types of problems. Finally, improved transpiration will help the cuttings to take in a proper supply of nutrients.

INTRODUCTION

The area of chrysanthemum in Holland declined from 755 ha in 2002 to 566 ha in 2007 (CBS, 2008). Labor costs make it hard to compete with producers abroad and legislation is increasingly favoring recirculation of the nutrient solution. In the past 25 years many attempts have been made to change the crop from soil to substrate to better meet environmental demands and to open the way to automation and reduced labor costs. Publications on the various systems include sand beds (Wilson and Finlay, 1995) sub-irrigation systems (Van Os, 1980; Buwalda et al., 1994, 1995; Warmenhoven and Baas, 1995) aeroponic and flow systems (Van der Hoeven and Zwinkels, 1991; Sakamoto et al., 2001) and various gullies including those of the DENAR project (Van Emmerik, 1994; Vermeulen, 2009). More recently the consortium Mobisant tried new approaches to mobile beds and gullies (Vermeulen, 2009).

In 2006 a grower invested in a fully automated solution, the MobyFlowers system. The basic unit is a square white polyethylene U-shaped outer gully of 5.0×5.0 cm and 8.00 m long (Figs. 1 and 2). In this gully a black polyethylene V-shaped inner gully of 5.0×5.0×5.0 cm stands on its tip. The top side is open, to be filled with a pre-fertilized 70% peat 30% coir mixture. The sides are perforated with slits which allow the roots to grow into the outer gully. Irrigation water is applied to the outer gully and runs down a 1% slope towards the drainage collection system at the end of the gully. The gullies start in a process hall where they are filled by a substrate dosing machine and then planted with cuttings by a planting machine. After receiving an overhead irrigation, a set of gullies is automatically moved to the second floor of the hall. The second floor is a propagation area with a top mist system, a sub-irrigation system and additional assimilation light. After 2 weeks the plants are about 15 cm tall and the gullies are transferred to the greenhouse. Gullies are spaced automatically and a wire net is added between the stems to provide support. In the cultivation greenhouse plants are sub irrigated until they are mature. The gullies are then transferred back to the process hall for machine harvest and subsequently cleaned, disinfected and filled again for the next production cycle. At MobyFlowers the irrigation of the gullies in the propagation phase starts by overhead irrigation with pure rain water. After 7-8 days a sub-irrigation cycle is given in the gullies with EC 2.7 $dS.m^{-1}$. This is repeated if necessary. After 16-17 days the EC is reduced to 2.4 $dS.m^{-1}$.

The main problem of the MobyFlowers system turned out to be the flower quality. Growth was unevenly distributed over plant positions within a gully and *Pythium ultimum*, mainly in the positions closest to the drain outlet, destroyed up to 10% of the crop during the summer season. The aim of the experiments described here was to mimic the problems, explain its causes and to advice on improvements (Blok et al., 2009). The working hypothesis was that within the first four weeks, high temperatures favor the incidence of *Pythium ultimum* while the abrupt changes in temperature and humidity made plants vulnerable for the disease.

MATERIALS AND METHODS

A measurement grid of T/RV meters was put in the MobyFlowers propagation greenhouse for 14 days. Results have been reported elsewhere (Campen et al., 2008).

The MobyFlowers system was mimicked in seven cultivations in three compartments in the facilities of WUR Greenhouse Horticulture in Bleiswijk (Table 1). The gully length was reduced to 4.00 m in cultivations 1 and 4 and to 1.35 m in cultivations 2-3 and 5-7. Cultivations 1 and 4 took place under moderate temperatures and elevated humidity (Table 1). Cultivations 2-3 and 5-7 were conducted in compartments with high temperature/low humidity climate regimes. In cultivations 2, 3 and 5 the high temperature/low humidity was created as a daily sudden increase respectively decrease. In the cultivations 6 and 7 the high temperature/low humidity were maintained continuously. In time the cultivations 1-3 ran parallel, as did the cultivations 4 and 5 and 6 and 7. The cultivations 6 and 7 compared a daily overhead hand irrigation with 10 L unfertilized rain water per square meter to the MobyFlowers mist system, part of which was rebuilt in the experimental station (Fig. 3). The MobyFlowers mist system ran for 10 s per pulse starting on a humidity of 90% or lower. It used unfertilized filtered water. The flow from the mist system was 30 $L.m^{-2}.h^{-1}$, that is 0.08 $L.m^{-2}$ per pulse. With 30 pulses per day (and often much more) that would be 2.4 $L.m^{-2}.d^{-1}$. The sub-irrigation system yielded 2.6 L fertilized water per gully per 2 min cycle.

Within the cultivations additional treatments were the use of plugs and a plastic foil cover. Plugs produced by a professional propagator were included as they would enable unhampered production if the propagation compartment had to be rebuilt. Instead of the traditional press pots for chrysanthemum triangular and speedling plugs were tested. The triangular plugs were 7.5×5.0×5.0×5.0 cm plugs (Fig. 4). They fitted the inner gully and were planted without substrate added in between them. The plants were stuck in one of the sides and the plug was planted with a tip pointing downwards. The speedling plugs were square with top dimensions of 18×18 mm and bottom dimension of 10×10 mm with a length of 26 mm (Fig. 5). These plugs were planted in the standard soil mixture. In both cases the plugs were made out of peat coir mass bound with a polymer foamed binder by the Jiffy company.

Plants kept for up to 9 days at three different locations were also compared. The locations were the MobyFlowers propagation compartment, a propagation compartment of the commercial chrysanthemum propagator Fides, and the compartments of WUR at Bleiswijk. The idea behind the comparison was to check that no factors other than those investigated were at play.

All irrigation tanks were inoculated prior to growing with surplus cultured *Pythium ultimum* isolated from diseased plants at the MobyFlowers greenhouse. The culture and multiplication by plating of *Pythium ultimum* was carried out in a specialized lab of WUR Greenhouse Horticulture. The disease pressure in the substrate was measured bi-weekly on suspected spots qualitatively and semi-quantitatively in samples analyzed by a commercial laboratory applying the DNA Multiscan® technique (Lévesque et al., 2001).

Water content and EC values were measured with FD water content meters but as no sensors small enough to fit in the gullies were available, readings were only indicative.

The cultivations 1 and 4 consisted of 8 tables with each 14 4.00 m gullies. 12 gullies were within the experiment, the outer 2 acted as guard rows. As there were 16 treatments (not all described here) it was decided to assign sets of 4 treatments to each table thus creating sets of 2 tables with the same treatments. Within each table the treatments were distributed as a random block design. This resulted in a minimum of 6 gullies with the same treatment per table. Each gully held 31 plants. Cultivations 2-3 and 5-7 consisted of 4 tables with each 14 1.35 meter gullies. 12 gullies were within the experiment, the outer 2 acted as guard rows. As there were 8 treatments (not all described here) it was decided to assign sets of 4 treatments to each table thus creating sets of 2 tables with the same treatments. Within each table the treatments were distributed as a random block design. This resulted in a minimum of 6 gullies with the same treatment per table. Each gully held 9 plants.

Position effects and mortality were visualized with regression lines (Figs. 6 and 7). Treatment effects of position, fresh weight and EC were analyzed with ANOVA (Figs. 6, 8 and 9). All statistics were performed with the GenStat program (Twelfth Edition).

RESULTS

Cultivations 1 (28 days) and 2/3 (each 14 days) ran parallel in time. Figure 6 shows the results of cultivation 1 dependent on the plant position. Plant position 1 is the plant closest to the irrigation supply, plant position 31 is the closest to the irrigation outlet for these 4.00 m long gullies. The triangular plugs show 17% lower fresh weight at the first eight positions of the gullies ($p<0.01$). The plugs became visually drier over time near the inlet. Covering the plugs with plastic foil resulted in 7% lower fresh weight at the first eight positions of that treatment ($p<0.01$) and increases the average yield over the gully length. The standard potting soil mixture results in the most even production with a fresh weight decrease of just under 5% towards the end of the gully. The speedling plugs showed a 12% higher fresh weight production in the first eight positions near the irrigation inlet ($p<0.01$). Cultivations 1 and 2 suffered uneven rooting. It was decided to introduce hand irrigation with unfertilized water for subsequent cultivations. As the 3-hour period with 28°C in cultivation 2 did not bring about any growth problems the temperature was raised to 30°C in cultivation 3. Still no *Pythium* was found and roots appeared healthy.

Cultivation 4 and 5 ran parallel and lasted 28 days. The first 10 days the gullies were top irrigated with a one minute hand irrigation per day, with about 10 L of rain water per square meter. Plants in the 20°C treatment were eventually dying in a position dependent pattern (Fig. 7). Up to 6% of the plants in the last positions were lost to rotting of the stem. This rot started at the lowest part of the stem and sometimes did not affect the cutting full circle. Testing for *Pythium* revealed that the initial rot of the cuttings was not a *Pythium* related problem. A week later however, the samples tested positive for *Pythium ultimum*. Plants in cultivation 5, the high temperature treatment, were much healthier and showed better root growth. At this point it was noted that plants kept the first nine days at MobyFlowers lagged 10% in fresh weight behind the standard treatment at Bleiswijk and root lengths were an order of magnitude, 90%, shorter. It was also noted that in cultivation 4, gullies covered with plastic foil produced almost 20% more than the same treatment without the plastic foil cover.

Cultivation 6 and 7 ran parallel for 14 days. The production difference between the two systems is over 30% in fresh weight and highly significant (Fig. 8, $p<0.001$). Tests on EC in the gullies were performed. Both, the EC when hand irrigating and the EC when mist irrigating dropped from an initial level of 2.4-2.7 to below 1.0 $dS.m^{-1}$ within days. The EC drop in the mist irrigated system was highly significant reaching values of below 0.1 $dS.m^{-1}$ which is virtually void of nutrients (Fig. 9, $p<0.001$). At day after planting 7 (DAP 7) the sub-irrigation system was turned on for once a day (2.6 L of EC 2.4 $dS.m^{-1}$ in 2 min per gully). The recovery from low EC levels when starting the sub-irrigation on day seven was slow in the hand irrigated system and almost imperceptible in the mist irrigated system. At this point additional measurements on the 8.00 m MobyFlowers units in the field at the grower's were performed. This confirmed that the EC over the length of these units ranged from almost normal at the nutrient inlet point to almost zero at the point of outlet.

DISCUSSION

Cultivation 1 and cultivation 4 differed only by the daily top irrigation applied in cultivation 4. Rooting became more uniform because of the top irrigation which helps to establish capillary contact between the base of the cutting and water held in the substrate. The higher water content caused by the hand irrigations combined with the gully length and the slope created higher water contents towards the drain outlet. Cuttings towards the drain outlet showed a higher incidence of root rot initially without *Pythium*. Within 7 days the rot included *Pythium ultimum* infection as *Pythium* favors free water to infect plants and senses leaking tissue (Van der Gaag and Wever, 2005). Triangular plugs at the high end of the gullies near the inlet produced poorly as they were too dry because of evaporation from all sides of the bare plug. Covering with plastic foil reduced the evaporation and therefore improved fresh weight production. The speedling plugs were planted in the standard potting soil and therefore became too wet and produced less fresh weight at the lower end of the gullies, near the drain outlet. As they are slightly more dense than the loose potting soil they tend to become slightly more moist than the potting soil.

The plants from MobyFlowers showed poor root growth. This is interpreted as the result of very high water content which is known to reduce either directly or indirectly through oxygen availability the growth of cuttings roots (Karlovitsch and Fonteno, 1986; Baas et al., 1997).

The hypothesis that abrupt and extreme climate changes in temperature and humidity cause the plants to succumb to the particular *Pythium ultimum* added, had to be rejected as the cultivations 2, 3 and 5 received sudden changes in climate but showed no elevated levels of *Pythium ultimum* in the rooting medium.

Finally the comparison of cultivation 6 and 7 (hand top irrigation versus mist top irrigation) proved the most important cause for growth and *Pythium* problems is the growth decline brought about by the MobyFlowers mist system. The mist system creates too coarse droplets which are at 1.00 m above the crop too close to evaporate before touching the crop and the substrate. As the supply rate is very low, there is ample time for the water to be transported sideways through the substrate. The suction force to drive this transport is derived from the 1 $cm.m^{-1}$ height difference between inlet and outlet and is thus influenced by gully length. Sideways transport results in flushing of nutrients out of the substrate in an increasingly efficient way towards the drain outlet. Thus the EC is near normal at the inlet and way below 0.5 $dS.m^{-1}$ near the outlet. Thus the water content is higher near the outlet and root growth and above ground fresh weight growth are lower. The misting system is starting when the air humidity drops, causing starts every 10-15 min in bright weather. Therefore the gully ends may stay over saturated for the whole day period. No sub-irrigation water can enter such fully saturated substrate. This explains why the sub-irrigation applied after D7 does not influence the EC of the mist irrigated substrate (Fig. 9, after the bar at D7). The circumstances for *Pythium* at the lower end of such gullies are extremely favorable for the swimming *Pythium* zoospores (Kläring et al., 2001; Schwarz and Grosch, 2003; Van der Gaag and Wever, 2005; Tsukiboshi et al., 2007).

In conclusion this mist system with unfertilized water should be abandoned. Any influence of plug form and foil cover in this experiment can be explained by influence on the distribution of water and nutrients.

A more general conclusion is that the design of cultivation systems should ensure the more systematic incorporation of plant related demands on climate control, rooting media and plant nutrition. This would help to avoid technical solutions with averse cultivation properties (Schroeder and Lieth, 2004; Vermeulen, 2009).

A second conclusion is that the lack of proper FD sensors to automatically measure and control water content and EC along the gullies is one of the reasons the causes of the problems remained unnoticed for some time.

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Tables

Table 1. Cultivations, main climate settings and top irrigation.

Cultivation (compartment)	Start date	Harvest date	T °C (d /n)	RH % (day)	Top irrigation D1-10
1 (9.01)	24-11-2008	18-12-2008	20/20	95-85-60	None
2 (1.11)	24-11-2008	5-12-2008	3 h 28/20	60	None
3 (1.11)	8-12-2008	22-12-2008	3 h 30/20	55	Hand irrigation
4 (9.01)	29-12-2008	27-1-2009	20/20	95-85-65	Hand irrigation
5 (1.11)	29-12-2008	26-01-2009	8 h 30/25	80-50	Hand irrigation
6 (1.11)	10-02-2009	26-02-2009	14 h 32/22	80-50	Hand irrigation
7 (1.12)	10-02-2009	26-02-2009	14 h 32/22	65-50	Top mist irr.

Figures

Fig. 1. Inlet and irrigation supply to white outer gullies with black inner gullies.

Fig. 2. Gullies with and without foil cover with fresh cuttings.

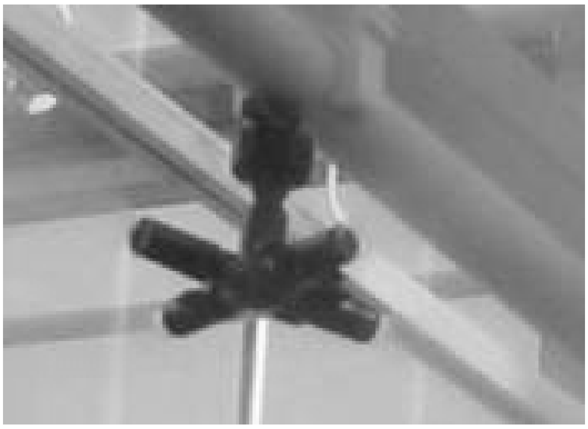

Fig. 3. A four headed nozzle of the mist system during misting.

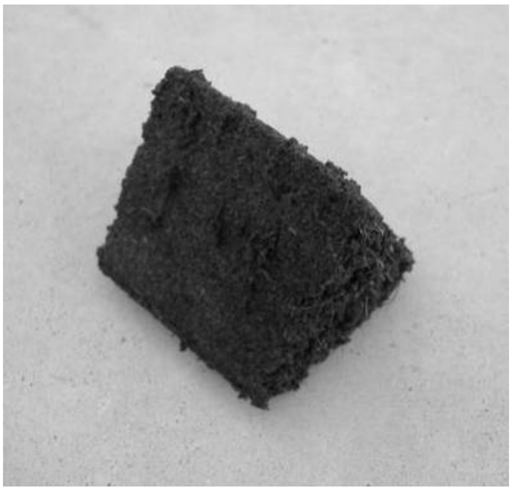

Fig. 4. Triangular plug for rooting chrysanthemum (upside down).

Fig. 5. Speedling plug for rooting chrysanthemum.

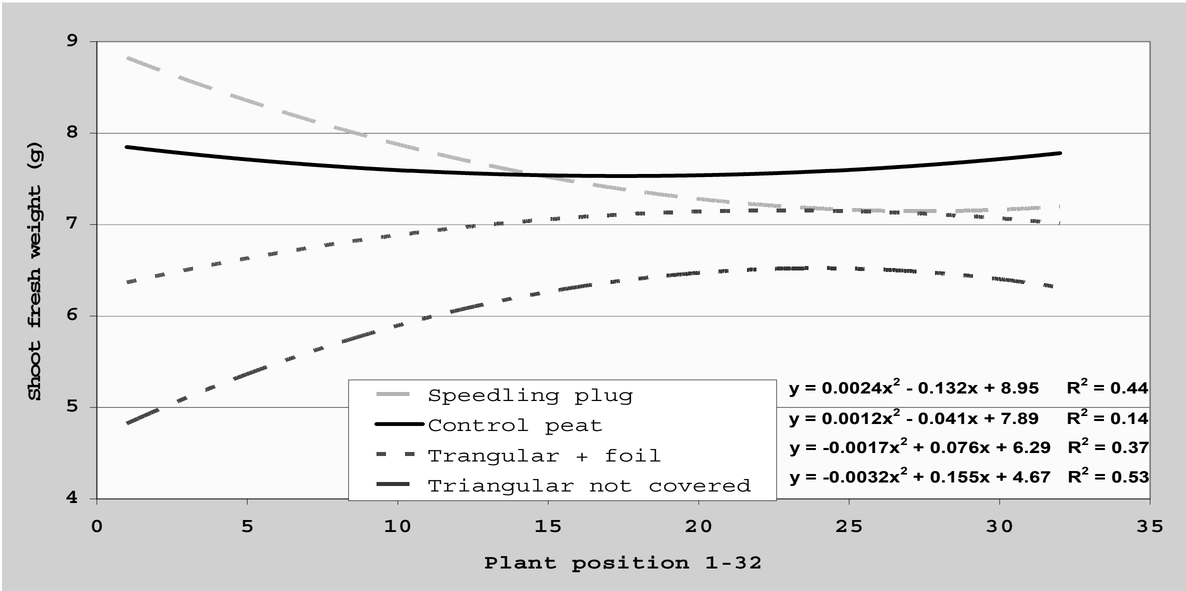

Fig. 6. Fresh weight yield per plant position for four treatments (cultivation 1). The production in the first quarter of the gully (position 1-8) is significantly higher than in the remaining three quarters for the speedling plugs (LSD-5% is 0.67) and significantly lower for the triangular plugs covered with foil (LSD-5% is 0.31) and triangular plugs not covered by foil (LSD-5% is 0.51).

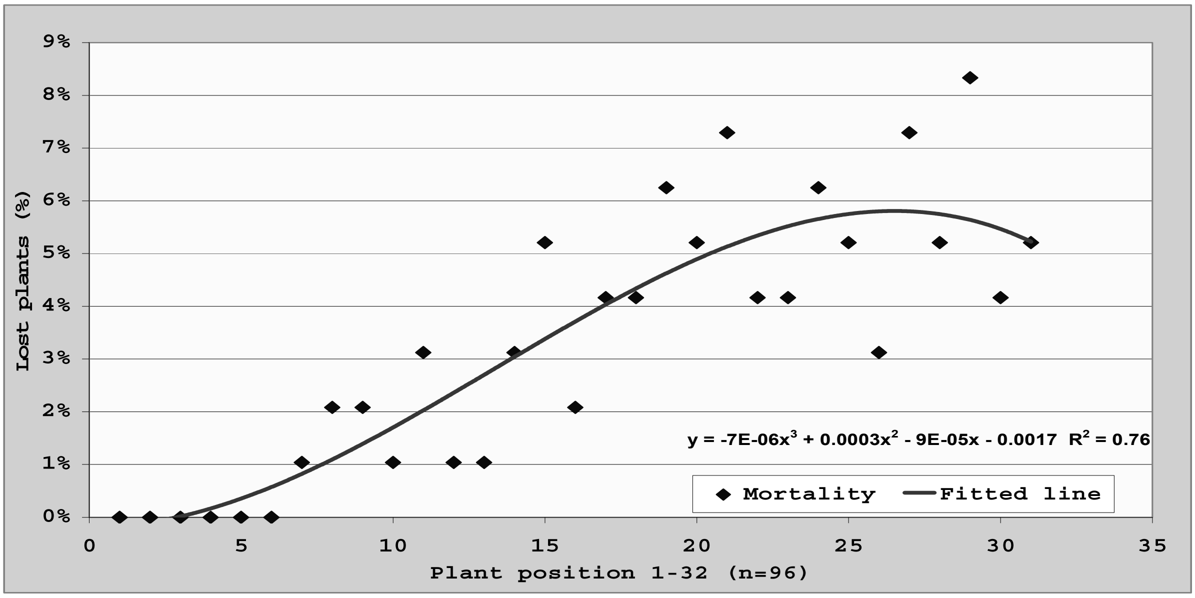

Fig. 7. Number of dying plants per plant position (all treatments, cultivation 1).

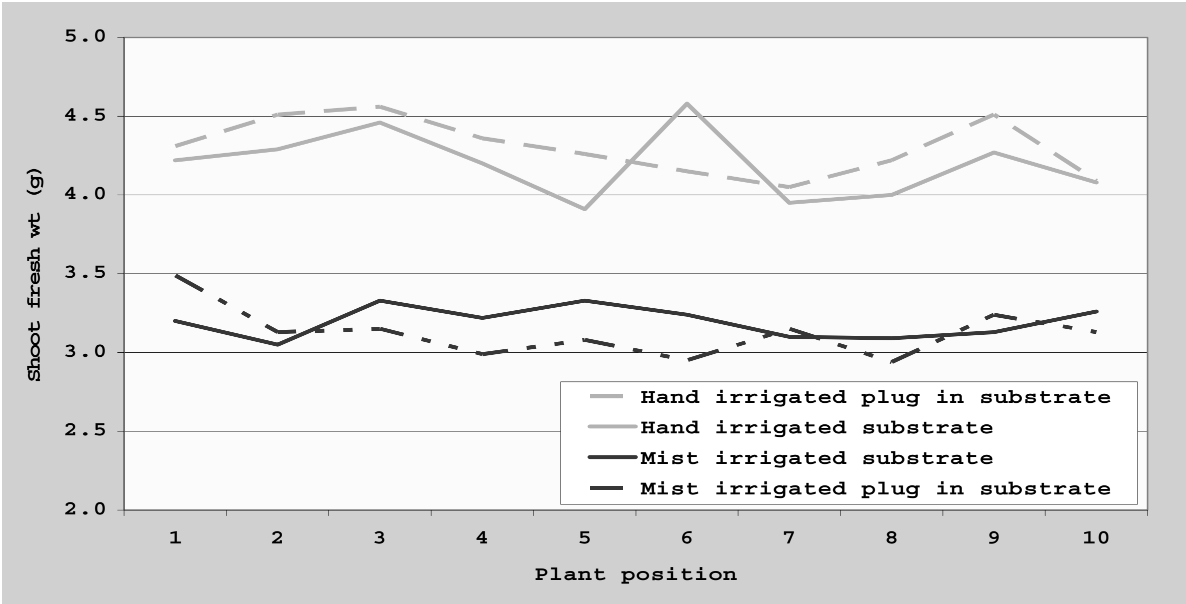

Fig. 8. Fresh weight yield per plant position for four treatments (cultivation 6 and 7). The LSD-5% for the treatments is 0.155.

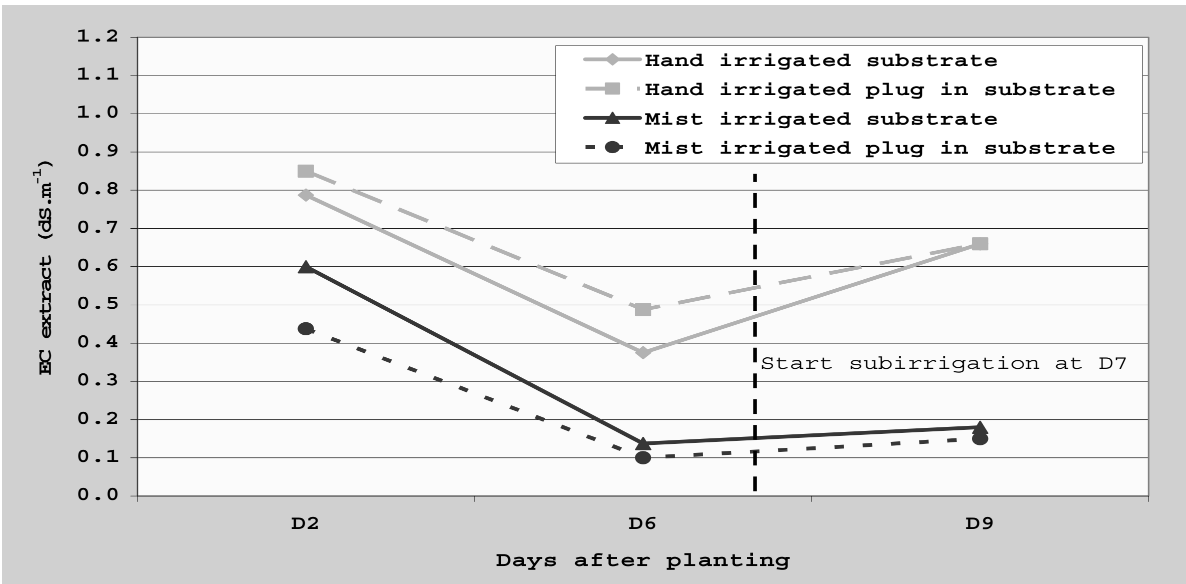

Fig. 9. EC in time for four treatments in the sixth and seventh cultivations. The bar at seven days after planting denotes the start of sub-irrigation once a day. The LSD-5% for the treatments is 0.076.