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Persistence of ancymidol in nutrient solutions used for flood irrigation of pot plants

Persistens af ancymidol i næringsstofopløsninger ved ebbe/flod vanding til potteplanter

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Summary

In an experiment with growth retardation of *Kalanchöe*, ancymidol of different concentrations was supplied once by subirrigation. For comparison, one concentration of ancymidol was applied twice by spraying the plants. The pots were placed on separate flooding benches for individual irrigation. On fixed dates after the ancymidol treatment, samples of the nutrient solutions were taken for analytical examination.

One week after irrigation with ancymidol, adsorption to the pot soil was obtained to an extent such that a balance equal to its K_d value approximately was achieved. After 3 weeks the concentrations were decreasing.

At the last sampling after 11 weeks 5–20% of added ancymidol was present in the solutions. From ancymidol supplied by spraying, about 5% was found in the solution after 11 weeks. However 5–10 times the amount of ancymidol is needed using foliar spray, compared to root supply, to obtain the same effect. Therefore the final residues of ancymidol in the nutrient solution will be higher after spraying than after root application.

It is concluded, to obtain full effect of the supplied ancymidol all plants belonging to one subirrigation system should be treated.

Analyses of primary ancymidol solutions for subirrigation, stored up to 4 weeks, showed no decrease in their concentrations.

After the cleaning of irrigation modules used for ancymidol treatments only insignificant residues were present.

Key words: Ancymidol, application methods, concentrations, persistence, residues, water analysis.

Resumé

I et forsøg med vækstregulering af *Kalanchoë* blev ancymidol udvandet på borde én gang i forskellige koncentrationer. Til sammenligning blev ancymidol udsprøjtet to gange i én koncentration.

Forsøget gennemførtes på separate vandingsmoduler med næringsstofopløsning tilført efter ebbe/flod systemet. På fastsatte tidspunkter efter behandlingen blev der udtaget prøver fra næringsstofopløsningen til analytisk bestemmelse af ancymidol-indholdet.

1 uge efter udvanding af ancymidol var der adsorberet så meget til pottejorden, at ligevægtstilstanden svarende til stoffets K_d-værdi tilnærmelsesvis var opnået. Efter 3 uger var mængden af ancymidol faldende.

Ved den sidste prøveudtagning efter 11 uger fandtes 5–20 pct. af de tilførte mængder i opløsningerne. Af den udsprøjtede mængde fandtes på samme tidspunkt ca. 5 pct. i næringsstofopløsningen. Da der imidlertid skal bruges 5–10 gange så meget ancymidol ved sprøjtning som ved udvanding for at få samme virkning, bliver slutkoncentrationen i næringsstofopløsningen større efter sprøjtning end efter udvanding.

For at opnå fuld udnyttelse af det tilførte ancymidol skal alle planter i et ebbe/flod vandingssystem behandles.

Analyser af stamopløsninger til udvanding viste ingen nedgang i ancymidol-koncentrationen ved opbevaring i indtil 4 uger.

Efter rutinemæssig rengøring af vandingsmoduler fandtes der ikke rester af ancymidol i en størrelsesorden, der har betydning for plantevækst.

Nøgleord: Ancymidol, behandlingsmetoder, koncentrationer, persistens, rester, vandanalyse.

Introduction

Flooding benches are now commonly used by pot plant growers.

Ancymidol (trade marks: Reducymol, A-Rest) is a growth retarding chemical with a long-term effect in pot plants when added to the nutrient solution (1,2,3,4). It has a growth retarding effect in about two thirds of the tested plant species (8). Ancymidol inhibits three steps in the gibberellin biosynthesis (9).

When ancymidol is applied by spraying on the plants, 5–10 times the amount of the substance should be used, compared to application to the roots, if the same effect is to be achieved (2,3,6,11).

However, a soil drench in each pot is labour intensive compared to a foliar spray. Therefore new methods of application have been developed to reduce labour and to secure a more uniform distribution of the substance than by spraying. The methods are: addition of the solution with the growth regulating substance either to the recirculating nutrient solution (2,3,4), or as subirrigation in flooding benches (6).

In an experiment with *Aeschynanthus* (5) the growth retardants were supplied to the recirculating nutrient solution. Analyses of the nutrient solution showed, that the concentration of ancymidol decreased throughout the experimental time. Initially there was an adsorption to the pot substrate until a balance defined as the K_d value of the substance in the actual substrate was attained. It was concluded that adsorbed ancymidol forms a reserve which is gradually released from the substrate to the nutrient solution, replacing the lost ancymidol. The present analytical examinations were carried out to show, what happens to the supplied ancymidol when pot plants are grown in flood irrigation systems.

The basis for this work is an experiment with plant growth regulators used in *Kalanchoë* cultivation in flooding benches (6). Solutions with different substances, among others ancymidol, were supplied by subirrigation or sprayed on the plants. At different times samples of the nutrient solution were analysed for the content of ancymidol.

In practice the growth regulator may be applied as a separate solution, from which the excess solution is removed and if convenient applied later. Therefore this has been considered in the experimental plan. It is also the reason for a small scale experiment on the persistence of ancymidol in the basic solution. Although, chemical degradation is not to be expected at pH values normally maintained in nutrient solutions (5).

Materials and methods

The experiment with growth retardation

The experiment was carried out with two cultivars of *Kalanchoë blossfeldiana* v. Poelln., cultivated on flooding benches as described by *Adriansen* (6). The two cultivars were delivered in different

substrate mixtures. The main content in each substrate mix was peat. Also, both contained clay, about 40 kg/m^3 of pot soil.

At the beginning of the experiment, 12 February 1987, Reducymol (0.25 g ancymidol per litre) was added to the benches of the experimental units (Fig. 1) as a 1 litre solution containing 2.5, 5 or 10 ppm ancymidol (Table 1). During the 20 minutes the bench drain was closed, the pots had absorbed about 600 ml per unit, corresponding to an average of 50 ml per 11 cm pot. This was demonstrated in a test arrangement. Other plots were treated by a foliar spray with 50 ppm ancymidol, 120 ml per unit, corresponding to an average of 10 ml per pot. The foliar sprays were applied twice, 12 and 24 February, while the plants stood on the experimental units. During the spraying, the treated plants were separated from the others by a movable plastic screen. Foliar sprays were applied to just before run-off, and from the first treatment the plants were large enough to cover the pot soil. Therefore it is supposed that very little of the spray penetrated to the soil surface.

The experiment was performed with two replicates. Each replicate consisted of one irrigation unit per experimental plot. Six pots of each cultivar were placed on each unit.

The nutrient solution was not renewed during the experimental time. However, once a week the content of water and nutrients in the tanks were adjusted to the initial level.

Samples for ancymidol analyses were taken from the nutrient solution in the tanks on the same day as ancymidol was applied, and again after 1, 3 and 11 weeks. Each time 1/2 litre was sampled from each unit. The first samples were taken after the first »flood«, within one hour after application of ancymidol. Before the later samples were taken, the solution in the tanks was made up to the 25 litre level, securing a more correct calculation of ancymidol residues. After arrival at the laboratory the samples were frozen.

Supplementary examinations

In the laboratory ancymidol was supplied in different amounts to mixtures of nutrient solution (measured) and pot soil (weighed). After careful mechanical mixing and storage for 24 hours or one week the concentrations of ancymidol were determined in the solutions. From these determinations K_d values were calculated for each of the two pot substrates. The K_d value is the proportion between adsorbed ancymidol per kg dry matter of soil and dissolved ancymidol per litre of water.

To establish some knowledge about the persis-

Table 1. Experimental plan for ancymidol application.
Forsøgsplan vedrørende ancymidol-tilførsel.

Treatment no. *Forsøgsled*	Method *Tilførselsmetode*	Volume supplied *Mængde tilført* litre *liter*	Concentration *Koncentration* ppm ancymidol	mg ancymidol Net/module *Netto/modul*
Ubehandlet *Untreated*				0.0
1a	Subirrigated, excess solution completely removed *Udvandet, al overskydende opløsning fjernet*	1	2.5 5.0 10.0	1.5 3.0 6.0
1b	As 1a, 1/10 of excess supplied again *Som 1a, 1/10 af overskuddet tilført igen*	1	5.0	3.2
1c	As 1a, 1/5 of excess supplied again *Som 1a, 1/5 af overskuddet tilført igen*	1	5.0	3.4
2	Subirrigated, no solution removed *Udvandet, overskydende opløsning ikke fjernet*	1	2.5 5.0 10.0	2.5 5.0 10.0
3	Foliar spray *Sprøjtning*	2 × 0.12	50.0	2 × 6.0

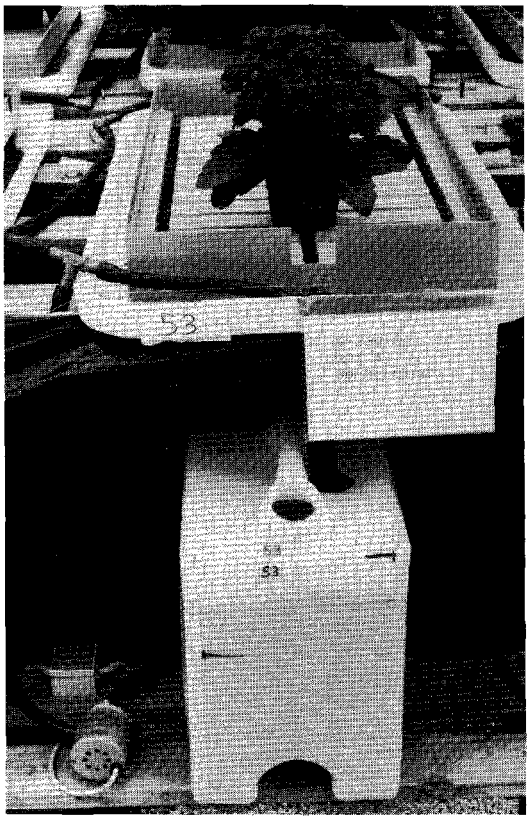

Fig. 1. A flood subirrigation unit used in the experiment with *Kalanchoë*. Each unit consisted of a tank (25 litre) with the nutrient solution, a pump (4.0–4.5 litre per minute), and a plastic tray. On the tray a Gari-Dana module (42 × 78 cm) was placed.
Et undervandingssystem brugt til ebbe/flod vanding i forsøget med Kalanchoë. *Hver enhed bestod af en dunk (25 l) med næringsstofopløsning, en pumpe (4,0–4,5 l/min.) og en plasticbakke. På denne var der anbragt et Gari Dana modul (42 × 78 cm). (Foto: E. Jensen).*

tence of ancymidol in the basis solutions for application, an experiment was carried out in the laboratory, where nutrient solutions with 5 ppm ancymidol were stored. Duplicate samples were taken for ancymidol analysis after 1, 2 and 4 weeks and compared to a sample analysed just after mixing.

Before benches and tanks are used for new batches of plants, they are cleaned and flushed, normally three times, with tap water. The first time acetic acid is added to the tap water. Two irrigation units used for ancymidol treatments were examined to ascertain if this method of cleaning was sufficiently effective. After cleaning these units were run with the normal irrigation programme, but with tap water. One week later samples were taken for ancymidol analysis.

Analyses

From each of the thawed samples 100 ml extractions were made, as described earlier (5). After evaporation until dryness the residue was dissolved in 1 ml of methanol and filtered, using a small filter with a pore size of 0.45 μm. Separation of ancymidol from other dissolved substances and quantification was carried out by high pressure liquid chromatography using a RP18-column and a UV-detector. 10 μl was injected, and methanol/water (50/50) was used as eluant. The concentrations were calculated from the peak heights at 198 nm.

When ancymidol is supplied to nutrient solution just before extraction the recovery in the applied method of analysis is 90–100%. The detection limit is $\leq$ 1 μg/l. This is less than for the earlier applied gas chromatographic method (5).

Results and discussion

Samples from the *Kalanchoë* experiment

The concentrations of ancymidol in the nutrient solution samples are shown in Table 2. For each treatment they are compared to the concentration which was to be expected at the beginning of the experiment, if the net supplied ancymidol had been added to the 25 l of nutrient solution in the tank. It is not taken into account that about 2% of the residual amount of ancymidol in the nutrient solution was removed with the samples. But as nearly one half of the ancymidol (see later) was adsorbed to the pot substrate, this source of error in the following sampling is only 1%, approximately, which means about 3% of the concentrations on the fourth sampling date.

Between replicates only random differences appeared. Therefore, Table 2 is based on the average of the two replicates. This is also the case for Fig. 2, which shows the relative amount of ancymidol determined.

The relation between supplied and determined ancymidol is fairly constant within sampling dates and treatments. Neither in treatment no. 1 (a+b+c) nor in treatment no. 2 (see Table 1)

Table 2. Ancymidol in nutrient solution after treatment applied 12 February by subirrigation, and 12 and 24 February by foliar spray. Average of two replicates.
Ancymidol i næringsstofopløsning efter behandling foretaget den 12. februar ved undervanding samt den 12. og 24. februar ved sprøjtning. Gennemsnit af to gentagelser.

Treatment *Forsøgsled*	µg ancymidol/litre *liter*				
	Net supplied *Tilført netto*	Determined in samples taken the day and month *Fundet ved prøveudtagning d.*			
		12.02	19.02	05.03	30.04
1a	60		44		11
	120		68		19
	240		167		42
1b	128		83		25
1c	136		103		24
2	100	51	51	37	5
	200	127	121	90	28
	400	205	203	147	50
3	2 × 240	13	31		23

there are significant differences between the residues from different doses, expressed as % of the supplied amount.

In samples from the nutrient solution taken on the day of application (treatment no. 2) a little more than 50% of the supplied amount was found in all the three doses. Consequently, nearly 50% remained in the pots. As found in the test arrangement, about 60% of the applied solution with ancymidol was absorbed by the pot substrate. This means that at least 10% of the total ancymidol amount was again leached in the first flood period.

The ancymidol concentration in treatment no. 2 after 1 week was the same as at the first sampling (Table 2, Fig. 2). This must be a random incident. Just after application, equilibrium between the content of ancymidol in the nutrient solution and the pot substrate, respectively, is not to be expected (cf. the adsorption experiment).

Analyses of samples taken after 3 weeks showed a decrease of the ancymidol content to an average of 40% of the supplied amount. After 11 weeks the ancymidol content in the nutrient solution had decreased to 5–15% of the supplied amount in treatment no. 2 (Fig. 2).

In treatment no. 1a, 1b, and 1c the surplus of the supplied ancymidol was removed, and for 1b and 1c partly supplied again. Compared to treatment no. 2, expressed in percentages of the supplied, there were more ancymidol residues in treatment no. 1 after both 1 and 11 weeks, as an average of the doses (Fig. 2). This difference is statistical significant. However, it is unessential and may be due to a smaller amount removed than presumed on the basis of the test arrangement.

Ancymidol seems to disappear from the nutrient solution more slowly by the present flood irrigation than by continuous recirculating (5). A possible explanation may be fewer pots per experimental unit, corresponding to about 3 litre less volume of pot soil, but with the same amount of nutrient solution, in the experiment with flood irrigation.

By spraying with ancymidol (treatment no. 3) only a small number of the drops directly hit the bottom of the benches. During the first week some ancymidol was leached from the pot substrate. In this period the relative amount of ancymidol in the nutrient solution increased from 1/10 to about 1/4 of the relative amounts resulting

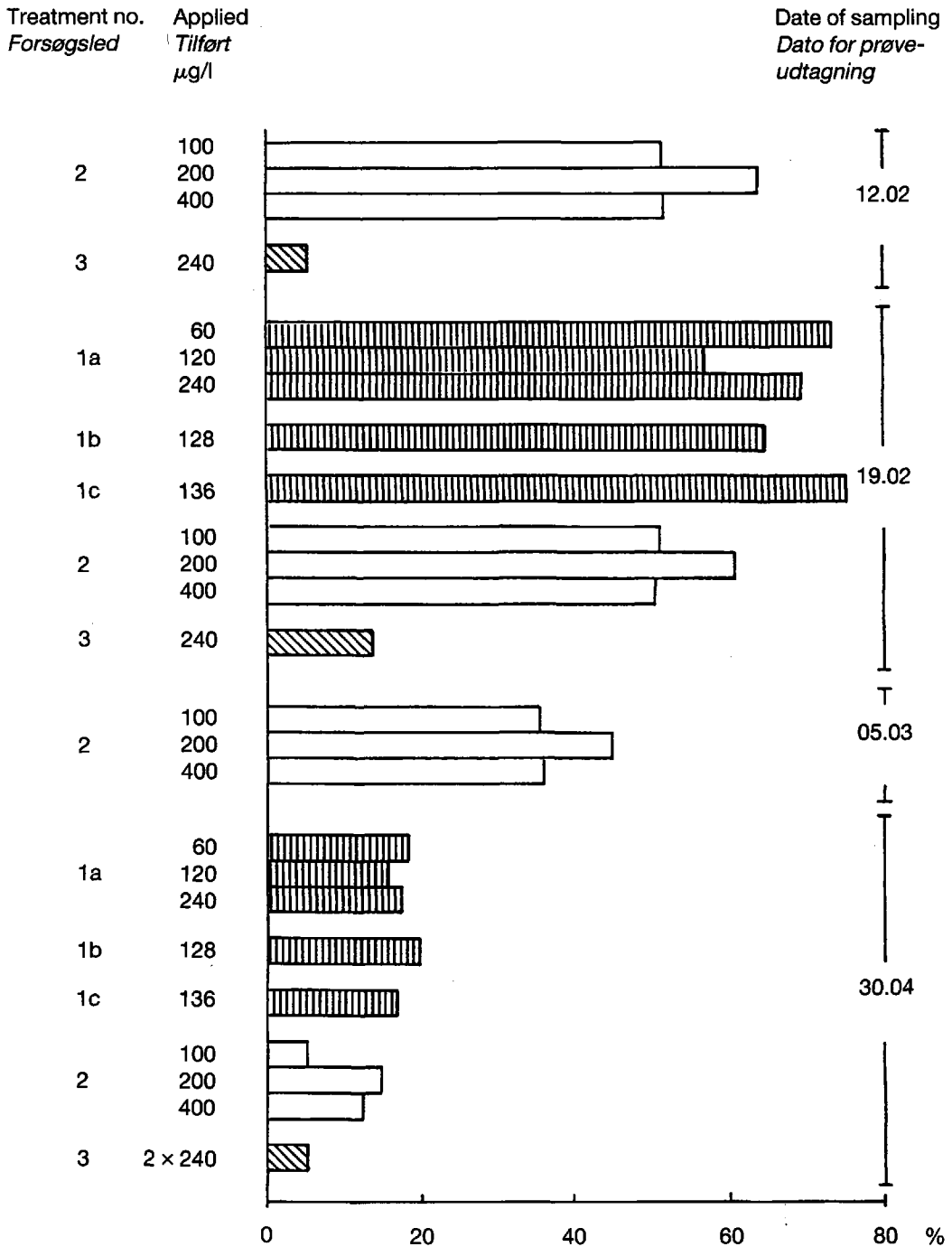

Fig. 2. Ancymidol in % of net supplied amounts, found in the nutrient solutions. Calculated on basis of the figures in Table 2.

Ancymidol, pct. af tilførte nettomængder, fundet i næringsstofopløsningerne på forskellige tidspunkter efter behandling. Beregnet på grundlag af tallene i tabel 2.

from ancymidol treatments by irrigation (Fig. 2). After 11 weeks (9 weeks after the second spraying) the difference was reduced additionally. At that time there was, as an average, nearly half the percentage left after spraying compared to irrigation. The total amount of ancymidol, supplied by two foliar sprays, is used in the calculation for the last sampling date.

It is notable that finally there will be at least double the amount of ancymidol in the nutrient solution after spraying than after root application, if an equal growth retarding effect is to be obtained, referring to the higher amounts of ancymidol needed for spraying (2, 3, 6, 11).

When spray applied ancymidol is leached from the pot substrate it may be a consequence of root exudation after translocation in the plant. Experiments with *Ulmus americana* have shown (10), that in plants injected with maleic hydrazide about 14% of the supplied substance was exuded from the roots into the nutrient solution. With ancymidol applied by spraying it is shown, that the leaves absorb it within 5 minutes (8). Further, ancymidol translocates from the leaves within 24 hours, and in a tall growing chrysanthemum cultivar the growth regulating effect are demonstrated after 3 days (7). This means, that ancymidol is moved quickly into and translocated by the plant. Fig. 2 indicates, that one week after spraying some ancymidol was exuded from the plants, if, as supposed, only a very small part of the spray volume reached the pot soil.

The adsorption experiment

Table 3 shows the distribution between pot soil and nutrient solution of the supplied ancymidol. The distribution is given as the K_d value for each concentration. Even though the values reflect some uncertainty, it appears that an equilibrium was achieved within 24 hours in soil 2, but not in soil 1.

In the recirculating and flood irrigation systems it should be expected that a longer time may pass before equilibrium is achieved, because only a smaller part of the water is in contact with the pot soil, and for an even shorter period in the flood systems. However, calculation of the K_d values on 19 February (treatment no. 1 and 2) results in numbers of the same order of magnitude as in Table 3. This indicates that the equilibrium was reached rather quickly, when the growth regulator had been supplied by subirrigation in the benches.

By flood irrigation one half or more of the supplied ancymidol is found in the nutrient solution shortly after application (Fig. 2). Therefore, all the benches connected to the same flood irrigation system should be treated to get the full effect of supplied ancymidol. If only a part of the benches within a system is treated it may be expected, that even more than the half of the supplied ancymidol will be leached from the pot soil and diluted in the nutrient solution, resulting in lower or no effect. In this case it would be necessary to supply more ancymidol.

Table 3. Ancymidol adsorption to two pot substrates in a laboratory test.
Adsorption af ancymidol til to pottejorde, bestemt ved laboratorieforsøg.
K_d-værdi: Forholdet mellem adsorberet ancymidol pr. kg tørstof af jord og opløst ancymidol pr. l vand.

Substrate *Jord*	Calculated amounts in mixture *Beregnet blandingsforhold*		Ancymidol added *tilsat*	K_d value after *K_d-værdi efter*	
	Soil, dry matter *Jord, tørstof* g	Nutrient solution *Næringsstofopløsning* ml	µg	24 hours *1 døgn*	1 week *1 uge*
1	7.59	157.41	3.75	30	74
	7.59	157.41	37.50	27	50
	7.59	157.41	375.00	23	50
2	6.65	158.35	3.75	65	61
	6.65	158.35	37.50	58	103
	6.65	158.35	375.00	43	32

The storage experiment

Analyses from the nutrient solution with 5 ppm ancymidol supplied did not show any significant decrease of the ancymidol content even after 4 weeks at room temperature in the laboratory (Table 4). So in the practice it is possible to make use of surplus solutions without loss for at least 4 weeks after mixing.

Table 4. Persistence of ancymidol stored at room temperature. The concentration was 5 mg ancymidol per litre of nutrient solution (5 ppm). Average of two samples.
Holdbarhed af ancymidol opbevaret ved rumtemperatur. Koncentrationen var 5 mg ancymidol pr. l næringsstofopløsning (5 ppm). Gennemsnit af to prøver.

Time of storage *Henstandstid*	% of initial concentration found *Fundet, pct. af startkoncentrationen*
1 week *uge*	101
2 weeks *uger*	99
4 weeks *uger*	98
$LSD_{(0.05)}$	n.s.

The effectivity of the cleaning

Analyses of the two water samples, taken for control of the cleaning of the experimental units used for ancymidol, showed values near the detection limit, i.e. about 1 µg/l. From our experiences such low concentration of ancymidol so far had no effect on plant growth.

Conclusion

When adding ancymidol solutions into the benches a great part is absorbed in the pots within 20 minutes. Within 1 week with flood irrigation, equilibrium between adsorbed and dissolved ancymidol is almost achieved. The attained level corresponds approximately to the K_d values determined in the laboratory. The time to equilibrium depends on the substrate components.

After 3 weeks the concentration of dissolved ancymidol in the nutrient solutions is decreasing, caused by degradation and uptake in the plants. After 11 weeks 5–20% of the supplied amount of ancymidol is still found in the nutrient solutions.

When ancymidol is sprayed on the plants to just before run-off, the nutrient solution at the beginning contains only small amounts of ancymidol, and 9 weeks after the latest spraying the content is about 5% of the totally supplied amount. 5–10 times more ancymidol is necessary for spraying than for drenching to obtain the same effect. Therefore the residues of ancymidol in the nutrient solution will be greater after spraying than after drenching by irrigation on the benches.

The supplied ancymidol is utilized best, if all the benches in a flood irrigation system are treated simultaneously.

Surplus ancymidol stock solution may be stored in at least 4 weeks, for later use.

No residues of importance are present after normal cleaning of the units applied for ancymidol treatments.

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