Modular Propagation

Technical Note
April 2020
Horticultural Dept

Stages in cauliflower transplant production: (left to right) the seeded tray, a tray ready for liquid feeding, plants ready for transplanting and a tray which has been held for an extended period by control of nutrition

History

The use of modules (multi-celled plastic trays) originated in the United States in the mid 1960's, spread to Britain by the early 1980's and growers in Ireland first began to use them around the mid 1980's. They have transformed the commercial production of several crops particularly brassicas. The advantage of using modules over bare root transplants include:

- allow propagation process to be mechanised
- provide a means of controlling seedling growth
- faster transplanting
- improve crop establishment, particularly under dry conditions
- improve crop uniformity.

Components of the system

Modular production is a complete plant propagation system under glass or polythene that can be fully mechanised. It's a multi-step process:

- trays are filled with peat compost
- seed is sown and covered with compost
- trays are stacked, covered with polythene and placed in a germination area
- after chitting, trays are laid out under protection and grown-on
- trays are taken outside to harden off.

Modular raised plants can be grown in a polytunnel tunnel or glasshouse

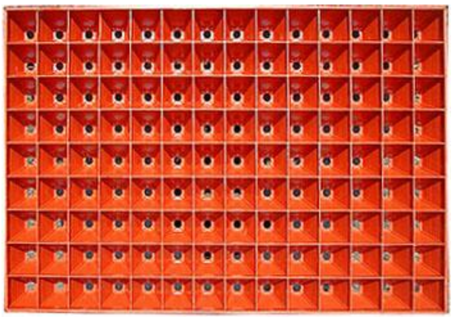
Overview

The propagation of good quality plants in cells requires not only a high standard of hygiene at all stages, but also considerable management expertise. Growers attempting this method of production for the first time are well advised to become fully briefed on the techniques involved. Raising plants is a seven days a week job.

Control of growth and development in cell-raised plants is effected in two ways: limiting the nitrogen and potassium available in the compost by carefully controlling the liquid feeding of these nutrients and by air-pruning the roots at the base of the module.

The tray

The trays are made of rigid polyethylene in a standard size of 60x40 cm with a variety of cell numbers. The original manufacturers of trays included Hassy, GPG and Alibert; all of these are now gone. There are no agents in Ireland for trays but second hand supplies may be available. Containerwise Material Handling are a Yorkshire based company that still manufacture trays.



GPG 126 modular tray

Although these trays differ slightly in cell shape and size, a very similar plant product can be grown in all of them. The 308 was the standard type of tray for brassica production but was superseded by the 345 which was of similar size, had the advantage of containing more cells per square metre and allowed for stacking in automated filling systems. A 336 is another commonly used size. For early production of brassicas some growers use the 216 tray that gives a slightly bigger plant for planting out. For overwintered crops use the larger cell sizes of a 126 or 216. These cell sizes are also suitable for crops like courgette, beans and tomatoes. Leeks are single seeded into a 504 or 600 whilst onions are multiseeded – to obtain 6 plants per cell, sow 6 or 7 seeds in each cell. The table below gives a representative selection of tray types but there are other cell number trays available.

Table1: Different tray types

Cell number	Volume (ml)	Cells per m^2	Crop
126	55	525	Beans, courgette, tomato
216	30	900	Early brassicas, celery
308	14	1262	Brassica, leek, onion, sweetcorn
336	19	1400	Brassica, leek, onion, sweetcorn
345	15	1439	Brassica, leek, onion, sweetcorn
600	11	2500	Leeks

Composts

The characteristics of a compost for use in cellular trays can be described in both physical and nutritional terms.

Compost for use in trays must run freely to fill the cells uniformly, but must not be so finely milled as to lose structure when watered. It must provide an excellent rooting medium to compensate for the small volume of the cell.

There are now various proprietary composts available specifically for use in small cells. They are usually based on a finely milled peat and may contain small proportions (five to ten per cent) of inert substances such as fine sand, perlite or washed vermiculite. Many of these composts contain a wetting agent even though the inherent structure of these composts eliminates the problems of re-wetting experienced with compressed peat blocks.

There are a number of composts on the market that are suitable for modules e.g. Bord na Mona Seedling Substrate Plus, Bullrush Modular Substrate. Available in 75 litre or 3 cubic metre bulk bags.

One of the advantages of growing plants in modules is the ability to control growth via nutrition. To allow this form of manipulation, the compost should be correctly limed and contain :

- all the micronutrients required for propagation
- all the phosphate required for propagation
- low levels of nitrogen and potassium to allow a plant to reach a post-cotyledon stage before liquid feeding need commence.

Seed

The cost of raising a tray of plants is fixed, regardless of the percentage of cells which contain an acceptable transplant. To maximise the number of filled cells it's essential to use seed only of the very highest quality both in terms of percentage germination and vigour. Economising on seed costs is expensive if subsequent quality of the plants suffer as a result.

In the image above the tray on the left has poor quality seed lacking in vigour which has resulted in a very uneven stand of plants. The tray on the right is what you are looking for – an even vigorous stand. With brassicas you are expecting a minimum 95% germination. With lettuce you may well get more and with Alliums perhaps a little less.

Seed may be treated or untreated. Treated or dressed seed has a coating containing one or more pesticides. It may be a fungicide or an insecticide, or a combination of the two. Thiram was the standard one for years but was discontinued in 2019. Apron (metalaxyl-M) and Maxim (fludioxonil) are still available and help to protect against, damping off, Phytophthora and downy mildew . Seed dressings can occasionally cause a depression in seedling germination and vigour.

Propagation area

It is important to have a hygienic propagation area and growing space. It should include:

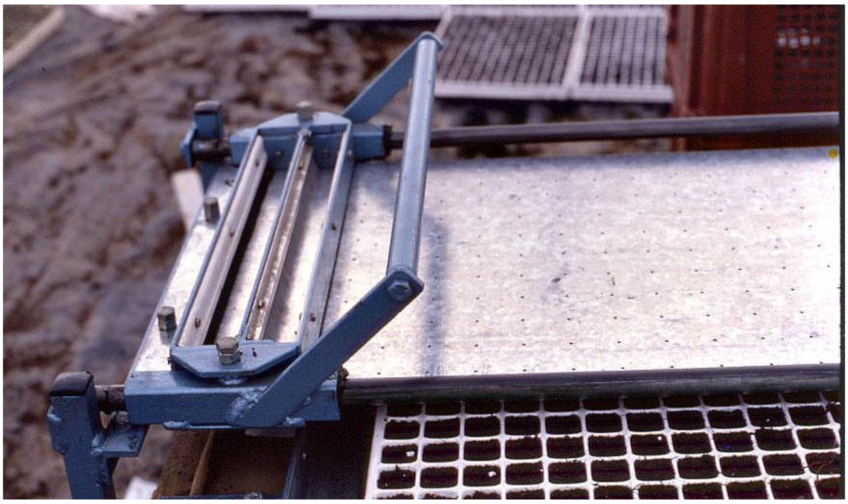
- a covered storage area for sterile trays and composts, so minimising contamination by chemicals or disease
- a work area for the filling and seeding of trays
- a means of applying water or fungicide drenches to the trays
- a germination room
- a hygienic and well-ventilated glasshouse or tunnel equipped for watering and feeding discrete cells uniformly
- a system to isolate the trays from the glasshouse floor to prevent rooting through and possible infection by soil-borne diseases.

Filling and seeding the tray

The method employed for filling the cells with compost will depend upon the throughput required and the labour available on the holding. On smaller holdings filling by hand can be efficient. On larger holdings, one of the proprietary filling lines is an advantage.

With small operations, it is possible to seed trays by hand. However, it is very monotonous and may lead to poor results. There are now a wide range of vacuum or plate seeders available which will seed complete trays in as little as 30 seconds. But a seeder which will adequately seed single brassicas may not be suitable for multi-seeded onions or beet. Suitability of the seeder for the crops to be grown should be checked thoroughly before purchase.

After seeding, the cells should be covered with compost or some other inert, free-flowing material such as vermiculite, excess above the cell division being scraped away to prevent cross rooting.



Example of a hand operated plate seeder – use different sized plates for different sized seeds.

Germination

Uniform germination is essential if the full benefits of the system is to be obtained. It is best achieved in a germination room or cabinet, particularly when temperatures outside the glasshouse are low. Such a unit consists of an unlit, moisture retentive area where uniform temperature conditions can be maintained. The optimum germination temperature for most crops is about 21°C. But take note that there are upper temperature limits for certain crops. Butterhead lettuce will not germinate well at temperatures above 25°C, leeks and onions will not germinate well above 21-24°C and celery germinates best between 15-20°C – much higher and it won't come through. Be careful of covering seed trays with glass or polythene – during hot sunny weather if the temperature of the compost goes above 35-40°C you will end up killing the seed. Consider using damp newspaper or polystyrene sheets in these situations.

The period for which different crops should be left in the germination room varies. For example, brassicas at 21°C should be removed after 36-48 hours. It is important to remove trays of all crops, except onions and leeks, to the light before emergence, or the seedlings will etiolate (elongate). Trays of onions or leeks can be left in the germination room after emergence for up to one week without harmful effects, as long as trays are not stacked on top of each other.

If you don't have a germination room or if ambient temperatures are sufficient lay the trays directly into the growing area.

System components: plastic tunnel, trays, wooden rails, Mypex on the floor, irrigation system, hand lance for top-up watering

Handling

Trays will have to be moved from the seeding/ filling areas to the germination room and then into the growing house. This is best done using a rack or stillage built on a conventional pallet.

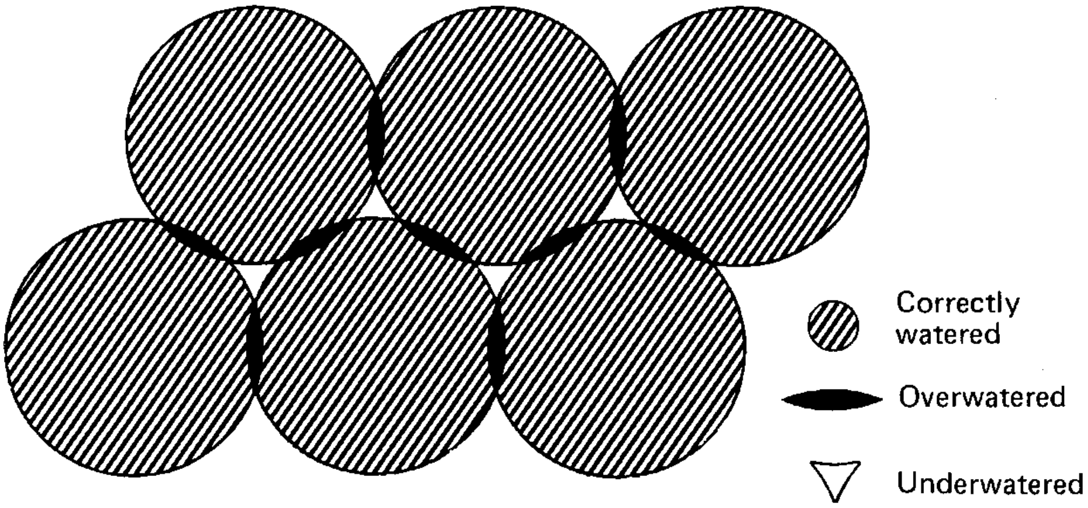
The trays should be laid out in the growing house in such a fashion as to enable plants to be brought out of the house in the order required, and to allow access for inspection.

When placing out trays in the house they require to be supported at least 5 cm above the floor to prevent rooting out into the ground and to ensure air pruning of the roots. Stand the trays on wooden slats, pipes, pots or bricks or on special benching.

Watering

The key to successful propagation in discrete cells is a watering system which will treat all cells identically. Overwatering of cells causes leaching of nutrients and consequent starvation of the plants. Underwatering leads to stunting and, in severe cases, plant death. Both problems lead to unacceptable variation within trays.

Traditional overhead watering systems do not give a uniform spread of water – see image below.



When raising bare-root transplants, this is not so crucial, since water can move sideways through the soil to some extent, and plant roots can also seek out water. In discrete cells there is no sideways movement of water and the plant roots are confined to their own cell. Consequently, unless watering is uniform, some cells in the tray will dry out, whilst their neighbours may be waterlogged.

Upgrading existing overhead systems by installing additional lines and more or finer nozzles may improve water distribution. However, it is unlikely to solve the problem completely unless a high pressure system of misting rather than drenching is used. The most efficient irrigation system is the travelling overhead gantry, which is in effect a spray boom which passes over the crop. This can be suspended from the glasshouse structure, run on the ground, or run on the heating pipes. Gantries are best designed to fit the needs of the individual house. Nozzles should be cleaned regularly to maintain uniform water distribution. A striped pattern in the crop indicates blocked nozzles.

Gantry watering system

Hand watering is also possible and can with experience be very accurate. In practice with any watering system, the outer cells of the outer trays in a block dry out quicker than the rest and some system of 'topping-up' by hand may be necessary.

The frequency of watering will depend upon the weather and crop growth. Trays should be watered when they show signs of drying out and not on any pre-determined timetable. Once a fortnight may suffice in winter, two or three times a week in spring, but during very hot summer spells, watering twice a day may be necessary. Watering should be to cell capacity, not to run-off or run-through, otherwise nutrients will be leached. As a rough guide up to 4 litres per m^2 will be required at each watering. To minimise disease pressure water early in the day to allow the plants to dry off before night fall.

Liquid feeding

By manipulating the feed it is possible to pre-determine the growth rate of transplants raised in discrete cells. Unlike bare-root transplants or larger modules, the propagator has complete control over these plants.

Feed should be applied through the irrigation system by means of an injector or a diluter such as a Dosatron. The injector generally gives a more accurate result. The frequency of feeding will depend on the crop, the compost, weather and the required growth rate.

Dosatron dilutor pump

If a compost is used with all of the necessary phosphate (P), but low levels of nitrogen (N) and potassium (K), then supplementary feeds with a N:K feed will be required for most crops. Potassium nitrate (13% N, 38% K) and urea (46% N) are mixed together in varying proportions to give a Low, Normal or High nitrogen feed, with Normal being the standard feed containing 100 ppm N and 200 ppm K. Alternatively potassium nitrate can be used on its own to give a 1:3 N/K feed; make up the stock solution by adding 7.8 kg to 100 litres of water to give a Normal feed of 100 ppm N and 300 ppm K when diluted at 1:100.

Examples of feeds utilising potassium nitrate and urea are given in Table 2.

Table 2: Liquid feeds

Stock solution		**Dilution**	**Feed strength**		**Nitrogen**	**Uses**
Potassium nitrate (kg/100L)	Urea (kg/100L)		N (mg/L)	K (mg/L)		
5.26	2.87	1:100	200	200	High	To produce fast growth or to re-activate plants held with low N.
5.26	0.69	1:100	100	200	Normal	Given two / three times a week will give sturdy growth.
2.63	0.35	1:100	50	100	Low	Given every watering will produce slow, sturdy growth. Given once a week will hold plants.

For details on how to calculate feed values using straight fertilisers or proprietary mixes, please see the Appendix.

The type and frequency of feed will govern the type of plant produced. As a guide:

- a frequent high N feed in summer will produce a cauliflower plant in less than four weeks – but the plant will be very soft and difficult to handle
- a high potash feed (i.e. a 1:3 or 1:2) at every second or third watering will produce a much hardier plant but will take longer to achieve a suitably sized plant
- as a rough rule of thumb brassica modules may require 3-5 feeds during propagation whereas sweetcorn may only require one.

The picture on the left shows nitrogen deficiency – a paleness of the older leaves. Use a high N feed to rectify. If you overwater modules you will very easily leach out nitrogen and potash.

Take note that UK sourced fertiliser always quote P as P_2O_5 (phosphorus pentoxide) and K as K_2O (potassium oxide). In Ireland we use elemental P and K. To convert P_2O_5 and K_2O to elemental P and K multiply by 0.44 and 0.83 respectively. Nitrogen in both countries is quoted in elemental N.

You require a licence to purchase potassium nitrate and some growers find it more convenient to use a proprietary product such as Solufeed which dissolves more easily, and also includes a dye for easier monitoring e.g. Solufeed 1:0:2. The option is also there to use a complete NPK feed if so desired e.g. Solufeed 1:1:1 or 1:1:3. Incidentally, those numbers refer to the ratio of N:P:K and not the percentage nutrient e.g. 1:1:3 has 12% N, 12% P_2O_5, 36%K_2O plus trace elements. The stock solution for Solufeed is made up by adding 1 kg to 10 litres of water and diluting at 1:100 or 1:150 or as required. Another brand is Kristalon 18-18-18 from Yara diluted at 1:100 – this time the figures do represent the percentage N, P and K.

Table 3: Using a proprietary feed

Solufeed 1:1:1				Solufeed 1:0:2			
	N	P	K		N	P	K
Percentage:	18%	7.8%	14.9%	Percentage:	16%	0%	28.2%
Parts per million:	mg/L	mg/L	mg/L	Parts per million:	mg/L	mg/L	mg/L
1:100	180	78	149	1:100	160	0	282
1:150	120	52	99	1:150	107	0	188
1:200	90	39	75	1:200	80	0	141

The above table gives an idea of how output values of a feed can vary by using different products along with different dilution rates. As a rule of thumb pick a combination of about 100 ppm N as your standard feed and increase the nitrogen to increase growth, or decrease it to slow growth. Parts per million (ppm) is equivalent to mg/L.

Multi seeded onions will require 2-3 Normal feeds of 100 ppm N and 200 ppm K, the first being given at the first leaf stage (about 4 weeks after sowing). The plants can with advantage be given a High nitrogen feed just prior to planting.

Celery should be fed frequently with a Normal feed to create a vigorously growing plant that can be planted straight out of the house before any root death occurs.

Trace element deficiencies do not usually show up in modular grown plants as they are normally added to proprietary composts and feeds and the life cycle of such plants are short. However if you are using hard water there is a chance that this may push up the pH of the peat which in turn may induce an iron deficiency.

Iron deficiency in brassica modules - pH of the peat was 7.4 due to hard water

Holding and storage

When plants run out of feed, growth slows and the plants can be 'held' for considerable periods. For demonstrational purposes, cauliflower plants have been sown in mid-March, grown slowly with low nutrient levels for up to 26 weeks before transplanting, and subsequently produced marketable heads.

However, it is important that crops are not completely starved during holding (see Table 2), otherwise it may be difficult to start the crop into growth again; older leaves may die and this can affect crop performance.

Cell-raised plants can also be held in cold store for up to two weeks without deterioration. After this period, the plants should be returned to the glasshouse, fed and watered, and allowed to revive. This usually takes about two days; they can then be returned to cold store for a further two weeks if necessary. Where irrigation in the field is available, longer periods in store can be considered.

After being held by controlled nutrition or in a cold store, plants in small cells must be given at least one high nitrogen feed and preferably several in the days before transplanting. This revives the plants, re-establishes a growing rhythm and ensures good establishment.

Propagation times:

Sweetcorn: 3-4 weeks
Multi seeded onions: 8-10 weeks
Leeks: 10-12 weeks

Brassicas: 5-7 weeks (typically 6 weeks)
Celery: 9-10 weeks

Hardening off

Modular plants are normally hardened off before planting out in the field to reduce the shock to the plant – particularly for early plantings. Later planting often go straight from the propagation house to the field. To harden off the modules are stood outside in a sheltered area for a week or so to enable the plants to become accustomed to cooler temperatures and less frequent watering. This process stimulates the plants to accumulate carbohydrate, nutrient reserves and strong cell walls by exposing the plants to day and night temperature fluctuations, increased air movement and wind, reduced watering, and full light.

Broccoli hardening off outdoors; Brassicas will often develop purple hues when hardening off - this is entirely natural

Transport to the field and treatment on the headland

Transport to the field is usually done in similar stillages to those described under 'Handling'. Whatever the means of transport, care must be taken to prevent desiccation of the plants during transport. Ideally, plants should not be held on the headland, but planted immediately. If plants cannot be set out within 48 hours, they must be unloaded, fed and watered; in other words, given the same level of management as if they remained in the care of the propagator.

Transplanting

Plants raised in cells have the potential to establish rapidly and uniformly. It is essential that trays of plants must be thoroughly watered, or preferably fed with a high nitrogen feed, just before planting. The application of water or a nutrient to the root ball at planting may also prove beneficial.

There are a range of planting machines available, usually 2 or 4 row, that are designed to plant modules. Planting distances and depth of planting are easily adjusted.

Two-row Windle planter at work

Tray hygiene

Soil-borne diseases e.g. clubroot, may carry over on the tray from one round of plants to the next. In practice, it has been found that soaking trays in a sterilant is effective in killing disease organisms. Use something like Endosan (hydrogen peroxide) or Jet 5 (peroxyacetic acid). For Jet 5 soak for 5 minutes using a 1% solution and leave to drain for 1 hour. There is no need to rinse off the sterilant.

Trays can be washed with a power washer whilst on a larger scale you can get a line to knock stray peat from cells, on into the washer and into the steriliser.

Heat

Heat is not normally applied to tunnels or glasshouses for plant raising purposes. However early production of broccoli sown in late January or February will require heat. The early celery crop sown in February requires heat to prevent bolting. When using pelleted celery seed, germination temperatures of 15-18 °C in the growing medium is essential during the first 4-5 days after sowing. Speed of emergence and uniformity will be reduced if the temperature is too low. Unless germination takes place in a germination room use Styrofoam boards to cover the trays and remove as soon as the pills have split. After germination normal cultivation temperatures should be maintained but to prevent bolting early sown crops require a minimum temperature of 16-18°C.

Cold damage to sprouts (left) and broccoli (right) - causes a distortion of the leaves

Plants can get frosted if the temperatures drop low enough. This is more likely to happen under polythene than under glass. This cabbage leaf shows frost damage symptoms but will grow out of it. Covering trays with a layer of fleece will help prevent cold damage.

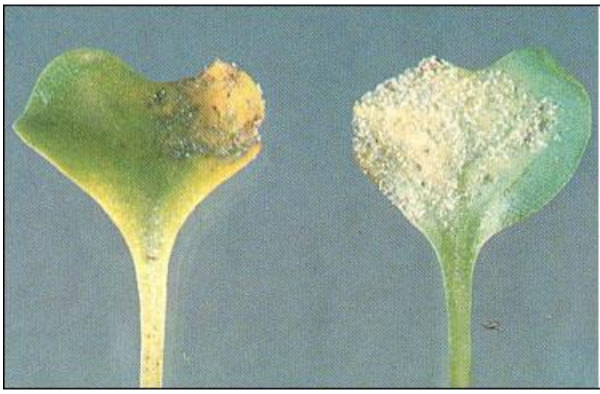
Disease control

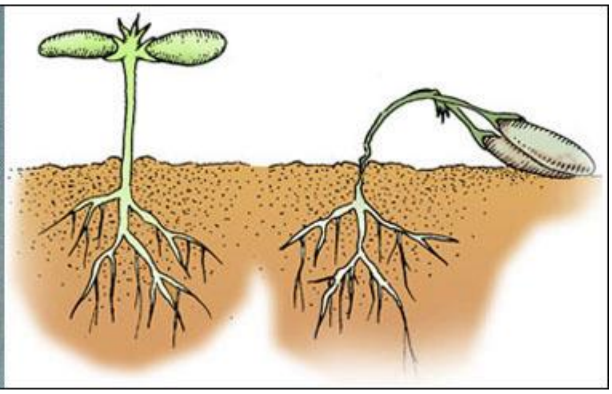
Damping off caused by Pythium on coriander grown in border soil

Damping off, which is a disease that causes collapse of seedlings can attack a wide range of crops but is seldom found in modular production as very often the seed is treated, the peat that is used is pretty sterile and trays are washed and sterilised. Damping off organisms include Pythium, Phytophthora and Rhizoctonia. On celery Pythium can cause damping off and a root rot; root rot can also be caused by Phoma. Occasionally Phoma can cause problems at the brassica seedling stage, showing up as canker. The main disease that occurs with brassica modular production is downy mildew – particularly on broccoli and cauliflower. Damping off and bottom rot can affect lettuce seedlings. Alliums are generally trouble free from both pests and diseases in the propagation stage.

All these diseases are encouraged by poor standards of hygiene and crop management. Sort these out before resorting to use of chemicals.

- Sterilisation of trays, nursery hygiene and good ventilation will go a long way in ensuring that crops get off to a disease free start and stay that way. Keep tunnel doors open at night to prevent excess humidity developing.
- To protect against damping off and initial attacks of downy mildew apply Proplant at 5 ml per m^2 in 2-4 litres of water applied to the modules as a drench immediately post sowing. Some growers will wait until the seed has chitted before applying – if this is the case ensure that the product is rinsed off any seedling leaves with clean water.
- Previcur Energy can be used instead of Proplant to control damping off and early downy mildew. Apply at 3 ml per m^2. There is also a foliar recommendation for the control of downy mildew on lettuce using 2.5 l/ha. Previcur Energy is a mixture of Proplant and Aliette.
- Foliar applications of Previcur Energy (8 ml/L) can be alternated with Ridomil Gold (4 g/L) every 10 days to control mildew.
- In the UK there's an off-label to use Paraat against downy mildew on seedling Brassicas at 360 g/ha, maximum of 2 sprays, up to the 4 true leaf stage.
- Biopesticides: Serenade (Bacillus subtilis) at 10 l/ha is reasonably ok on downy mildew provided it is used preventatively and sprayed on weekly. Prestop (Gliocladium) is effective against a range of fungi including those that cause damping off.
- Phosphite based foliar feeds (Vitomex, Farmphos, Nutri-phite etc.) may have an effect on downy mildew if used preventatively.
- Downy mildew can overwinter as oospores, hence sterilisation of glasshouse structure and ground may help to reduce inoculum and initial infection.
- As a general rule trays that are at ground level will suffer more from disease than trays that are on waist height benching.





Downy mildew on Brassica cotyledons *Damping off*

Pest control:

- beware of damage from slugs especially near the edges of tunnels or glasshouses
- small birds can also be troublesome if they get into a house - they eat the seedlings just as they are coming up
- mice can occasionally cause a nuisance by eating seeds.

Cabbage root fly
The standard control is to treat with Verimark. The alternative and equally effective chemical is Tracer. However Verimark, which is systemic in action, is also effective against aphid, caterpillar and flea beetle for the first 6 weeks or so after planting. The drench is applied with a watering can or via a gantry system.

Verimark drench: 15 ml / 1000 plants

- wash Verimark off the leaves with clean water immediately after application
- total volume of water used must be just sufficient to soak the compost without run-off. If an excess of water is used the chemical will be washed out of the module leaving the plants at risk of cabbage root fly attack.
- apply no longer than 3 days before transplanting

Poor light levels at germination leads to stretched or etiolated seedlings. This can happen if the trays are left too long in a germination cabinet.

APPENDIX

Calculating liquid feeds

Bulk Tanks or Dilutors

There are two ways of preparing a liquid feed – bulk tank or use a dilutor. The dilute feed can be prepared in bulk in a tank and pumped straight through the irrigation system. This has the virtue of simplicity and accuracy and is useful especially on smaller holdings. It is important to have good agitation in the tank to ensure efficient mixing of the feed. More usually, a stock solution is made which is typically 100 times the concentration of the final feed. This stock solution is then passed through a dilutor to achieve the desired concentration. The dilutor must be calibrated and checked regularly to ensure accurate feeding.

Formulating Liquid Feeds

Once we know the desired composition of the liquid feed, we can calculate the fertilisers needed to prepare the stock solution.

To calculate the weight of fertiliser needed to provide a given concentration of a nutrient in the feed use the following formula:

$$\text{kg of fertiliser} = \frac{\text{Nutrient concentration (mg/l)} \times \text{dilution rate} \times \text{volume of stock solution (litres)}}{\text{\% nutrient in fertiliser} \times 10{,}000}$$

As an example, if we are using potassium nitrate (13% N, 38% K) and we want to make 100 litres of stock for dilution at 1 in 100 to provide a feed containing 100 mg K/l (i.e. 100 ppm K), then we calculate the amount of potassium nitrate as follows:

$$\text{Amount of potassium nitrate required} = \frac{100 \times 100 \times 100}{38 \times 10{,}000} = 2.63 \text{ kg}$$

The potassium nitrate also provides some N in the feed.

To calculate the concentration of a nutrient in the feed supplied by a given amount of fertiliser, use the following formula:

$$\text{Nutrient concentration (mg/l)} = \frac{\text{wt. of fertiliser (kg)} \times \text{\% nutrient to fertiliser} \times 10{,}000}{\text{dilution rate} \times \text{volume of stock solution (litres)}}$$

So in the example above we can calculate the concentration of N in the feed supplied by the potassium nitrate as follows:

$$\text{Concentration of N (mg/l)} = \frac{2.63 \times 13 \times 10{,}000}{100 \times 100} = 34 \text{ mg/l}$$

Using these formulae, we can now calculate stock solutions for any feed we want once we know the nutrient content of the fertilisers. The fertiliser can be from straights or from proprietary feeds – or from a combination of the two. A sample of commonly used straight fertilisers are shown in the following Table.

Nutrient Content of Fertilisers Used in Liquid Feeds

Fertiliser	Nutrient Content (%)			
	N	P	K	Ca
Potassium Nitrate	13		38	
Calcium Nitrate	15.5			20
Mono-potassium Phosphate		23	28	
Urea	46			

Suppose we want to make up a stock solution for a feed for modular plants containing 200 N, 30 P and 150 K. As in the previous example we will make 100 litres of stock solution which we will dilute at a rate of 1 in 100.

First calculate the amount of potassium phosphate to provide 30 mg P/l in feed:

$$\text{Kg of potassium phosphate} = \frac{30 \times 100 \times 100}{23 \times 10{,}000} = 1.3 \text{ kg}$$

This amount of potassium phosphate will also supply potassium as follows:

$$\text{Concentration of K supplied by potassium phosphate} = \frac{1.3 \times 28 \times 10{,}000}{100 \times 100} = 36 \text{ mg/l}$$

We still have a requirement for 114 mg K/l (i.e. 150-36). This can be supplied by potassium nitrate as follows:

$$\text{Amount of potassium nitrate} = \frac{114 \times 100 \times 100}{38 \times 10{,}000} = 3.0 \text{ kg}$$

This amount of potassium nitrate will supply N as follows:

$$\text{Concentration of N supplied by potassium phosphate} = \frac{3.0 \times 13 \times 10{,}000}{100 \times 100} = 39 \text{ mg/l}$$

This leaves a requirement of 161 mg N/l (i.e. 200-39). This should be supplied by urea as follows:

$$\text{Amount of urea} = \frac{161 \times 100 \times 100}{46 \times 10{,}000} = 3.5 \text{ kg}$$

So, 1.3 kg of potassium phosphate, 3.0 kg of potassium nitrate and 3.5 kg of urea dissolved in 100 litres of water and then diluted at 1 in 100 will provide a liquid feed containing (mg/l) 200 N, 30 P and 150 K.

Other feeds can be calculated in exactly the same way.

One other example. Say we are using Solufeed 1:0:3 and we want to make up a feed containing 100 ppm N and 200 ppm K using a 500 litre bulk tank. Solufeed 1:0:3 contains 13% N and 32.4% K. We will work out the 200 ppm K first. As we are using the feed direct from the tank the dilution is 1:1 and as the tank can fit 500 litres we will take that as our stock solution.

$$\text{Amount of Solufeed} = \frac{200 \times 1 \times 500}{32.4 \times 10{,}000} = 0.31 \text{ kg}$$

Next we need to work out how much nitrogen is supplied by 0.31 kg of Solufeed.

$$\text{Concentration of N supplied by Solufeed} = \frac{0.31 \times 13 \times 10{,}000}{1 \times 500} = 80.6 \text{ mg/l}$$

We are 19.4 ppm short of N (i.e. 100-80.6), hence the need to top up with urea.

$$\text{Amount of urea} = \frac{19.4 \times 1 \times 500}{46 \times 10{,}000} = 0.02 \text{ kg}$$

Water quality for plant raising

In Ireland we are lucky in that our water quality is generally very good. By far the most common problem is high bicarbonate content. The bicarbonate content (sometimes called the alkalinity) measures the ability of water to affect the pH of a propagation compost. It is important to remember that the pH of water is not a good guide to its alkalinity as soft water can often have a high pH.

The conductivity (EC) of water however is closely related to the bicarbonate content. If your water has a high EC then the chances are that it contains a high level of bicarbonate. You can add acid to the water to neutralise the bicarbonates and to bring the pH of the water down to 5.5-6.0. But using hard water to water modules is usually quite ok as the crops you are growing usually have quick life cycles. However cases have arisen where the pH in the module rises to such an extent that you end up with an induced iron deficiency.

Good quality water is that which contains nothing that is injurious to plant growth. So what can be in water that may affect plants ?

Toxic levels of an element : This is unusual. However one well source analysed at Kinsealy had over 5 mg/litre Boron (B). This would be toxic if used as irrigation water.
Sodium Chloride : This can occur in some water sources that are close to the coast especially in dry seasons. The salt, not directly toxic, contributes to high EC in the compost, especially if it is allowed to build up, and will put the plants under stress.
Iron (Fe) : Iron, although a plant nutrient, is not welcome in water. In the form that it is in, it will precipitate on exposure to air and leave a red/brown deposit on surfaces and leaves. It can also block filters and trickle irrigation systems.
High nutrient levels : This has occurred on a small number of glasshouse nurseries where the water source has become contaminated by drainage from the same or an adjoining nursery. These waters contain N and K which has to be taken into account when making liquid feeds.

Collected rainwater is ideal for irrigation as it's naturally soft and the pH is usually somewhat acidic as CO_2 dissolves in water as a weak carbonic acid.

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