Horticultural Growing Media and Plant Nutrition

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The Effect of Planting Density on the Production Of Potato Minitubers Under Protection

Introduction

Micropropagation of potatoes can be used to bulk up stocks of new cultivars or disease free stocks of existing cultivars. Rooted microplants are grown under protection to produce minitubers which undergo multiplication over a number of generations to produce seed potatoes. The object of these experiments, undertaken for Dubcap Ltd., was to study the effect of planting density on minituber production under greenhouse conditions. They were also designed to serve as a basis for assessing the feasibility for recycling minitubers especially small (8-15 mm) ones which have been shown not to perform satisfactorily under field conditions. The experimental system was designed to serve as a prototype for a commercial operation which would function as a satellite production site remote from the tissue culture laboratory.

Growing system

The growing system consisted of peat filled containers in a 20 m long, polythene lined, ebb and flood bed in a glasshouse. A reservoir with a capacity in excess of 8 m^3 was dug with an excavator and lined with polythene. A submersible pump in the reservoir was used to flood the bed. When the bed was being flooded a motorised valve on the drainage outlet return pipe closed, so as to contain the irrigation water in the bed. Subsequently the valve was opened and the bed allowed to drain off. A programmable timer was installed to control the operation of the pump and the motorised valve.

The containers were made of rigid mesh plastic and the external dimensions were 247 mm square. Container volume was 5 litres. The sides were slightly tapered and a growing unit consisted of a pair of containers tightly clipped together at the top. This meant that only one side of the base of each container was in contact with the floor of the flood bed and ensured good drainage away from the containers after a flooding cycle.

Planting density

Minitubers (8-12 mm diameter) of three cultivars, Golden Wonder, Maris Piper and Record were planted on April 11. The number of tubers planted per container ranged from 1 to 8. When the containers were laid out in the bed this gave a range of planting densities from 16.4 up to 131 tubers per cropped m^2. Each cultivar was grown as a separate experiment. To reduce the interference effects between different planting densities and to contain the experiments within a reasonable size, the treatments were laid out in a systematic design.

The plants were irrigated with plain water up to June 6 when nutrients were introduced and were subsequently given with every irrigation. Watering stopped on July 14 and the foliage was removed on July 21.

A second crop of three cultivars, Maris Bard, Maris Peer and Saturna was planted into the containers on August 2. In this crop watering ceased on October 17 and the containers were allowed to dry out before harvesting. On wilting, the tops were removed and the tubers were harvested from October 28 onwards.

Figure 1 : A healthy leaf canopy in the flood bed

Crop Growth

Shoot emergence in spring was slow and uneven with the first shoots of Maris Piper appearing 15 days after planting. and Record and Golden Wonder being another week later. The tubers used in spring were not sprouted. For the second crop, the minitubers were well sprouted, consequently, shoot emergence was rapid, about one week after planting, and uniform. Thus establishment of the crop canopy was much more rapid than in the spring planted experiments.

Figure 2 : An individual container at harvest

As the plant canopy developed, it was noticeable that the plants at the higher planting density were taller and more etiolated than those at the lower density. These differences became less noticeable as the crop progressed. Overall, plant appearance was good, the plants being a healthy dark green colour. In both crops, the plant canopy flopped leaving some holes in the canopy which gradually grew in again. This canopy collapse may have resulted in less than optimum arrangement of leaves and may have reduced the photosynthetic potential of the canopy.

Yield

Increasing the plant density had only a small effect on the weight of tubers harvested but increased the number including those over 15 mm diameter. The average tuber weight decreased as the planting density increased as did the multiplication factor. The weights of Maris Piper and Record harvested were similar and greater than Golden Wonder which had a lower average tuber weight. Yield results in the second crop were similar to those in the spring planted experiments with the number of tubers per crate tending to increase with planting density but the multiplier factor reducing sharply.

The expression in Equation 1 is commonly used to describe the relationship between plant density and yield where ω is the mean weight per plant, ρ is the number of plants per unit area and α and β are constants for a single set of data. This relationship implies that the yield per unit area increases with plant density up to a maximum and thereafter remains constant. The maximum yield per unit area is β^{-1}. Rearranging equation 1 and multiplying each side by ρ gives equation 2 where $\omega.\rho$ is the yield per unit area.

$$\omega^{-1} = \alpha + \beta\rho \qquad (Eq\ 1)$$

$$\omega\rho = \frac{\rho}{(\alpha + \beta\rho)} \qquad (Eq\ 2)$$

The results for the number of tubers with a diameter greater than 15 mm, for the three experiments, were fitted to equation 2 and the data for Maris Piper are shown in Figure 1. In this figure, the unit area is taken as an individual container (16.4 to the m^2). The economic optimum planting density will depend on the interaction between the value accorded to the seed tubers, the value of the harvested tubers (>15 mm) and other costs such as the flood bed, equipment, peat and containers. In order to provide yield forecasts for use in a cost prediction model, the values for α and β obtained in the 6 experiments were averaged to provide values of 0.096 and 0.048 respectively.

Cost of production prediction

The yield predictors were combined with estimated costing figures to study how the optimum planting density is affected by the cost of the planting material (Appendix 1).

The model is based on a unit of a polythene tunnel measuring 33 x 9.8 m. This is assumed to have a capital cost of £5,000 which is depreciated over 5 years in a straight line. Assuming two crops per year, this amount to a cost of £500 per crop. If 80% of the floor area is cropped then we need 4,240 crates to fill this space. At 35 p per crate this amounts to £1,490 or £149 per crop. The peat at 5 litres per crate amounts to £742 per crop which is a considerable cost. The return to the grower is put at £833 which is equivalent to £10,000 from a 6 house unit. Consumables are reckoned at £300 per crop. This gives a total cost of £2,524 per crop excluding planting material.

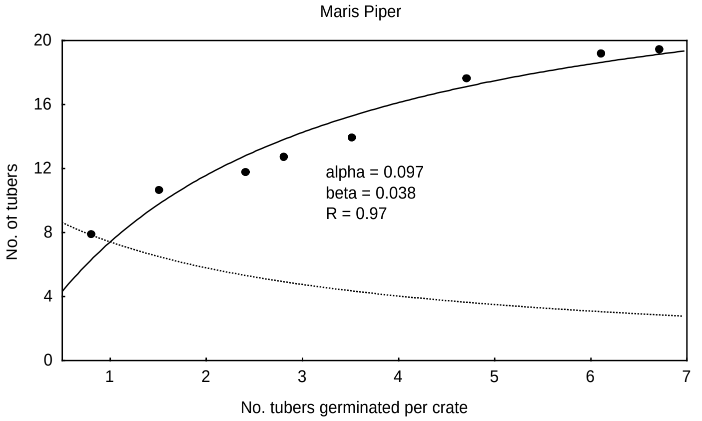

Figure 3: The effect of plant stand on the number of tubers (> 15 mm diam) harvested per container and the multiplication factor

The planting material cost was varied from 0 to 30 pence per tuber and the planting density per crate from 1 to 8. The mean yield predictors, were used to forecast the number of tubers produced. The cost of production per minituber was calculated for these 32 combinations and the results are shown in Figure 4.

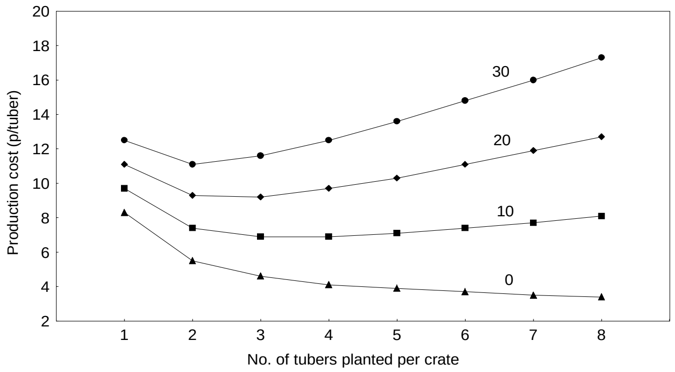

Figure 4 :The effect of planting density on the production costs of minitubers at a range of planting material costs (p/tuber).

If we take the optimum planting density as that which minimises the production cost of the minituber then it is evident that this will vary considerably depending on the cost of the planting material. When the planting material cost is zero or very low then the best planting density is high i.e. that which gives the maximum output per m^2. When it is very expensive then the multiplier factor becomes the important consideration and the optimum planting density falls to one per crate. This is illustrated in Figure 4 which shows how the production cost per minituber varies with planting density at a number of planting material costs and Figure 5 which shows the effect of planting material cost on the optimum density.

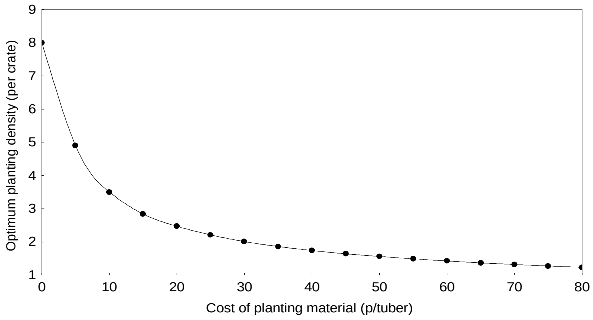

Figure 5 :The effect of cost of planting material on the optimum planting density of minitubers.

It is also evident that the cheaper the planting material costs, the lower the production cost of the minituber. Hence, it seems attractive to recycle the small (8-15 mm) tubers which do not succeed under outside conditions and which will therefore have a lesser value. It should also be considered whether microplants should be used in this system, with the harvested tubers over 15 mm diameter being sold on and the tubers in the 8-15 mm range being recycled back into the greenhouse system for one cycle.

Microplant experiment

The possibility of using microplants instead of minitubers was studied in 1996. The plants were transported from the tissue culture laboratory in sealed plastic containers to prevent desiccation. The microplants were planted into the peat filled containers on April 19. Plant density varied from 1 to 8 per container and were arranged in a systematic design as in the previous year. A separate experiment was carried out with each of three cultivars, Atlantic, Hermes and Nicola. The microplants established well with only a small number of plants needing replacement. The tubers were harvested on July 23.

The results for the number of tubers harvested per container were fitted to Equation 2 as in the previous year. The response of Nicola to planting density is illustrated in Figure 6. At low planting densities, microplants of Atlantic and Hermes produced less tubers with a diameter greater than 15 mm than did the minitubers of the previous season. The values found for β are similar to those found in the minituber experiment.

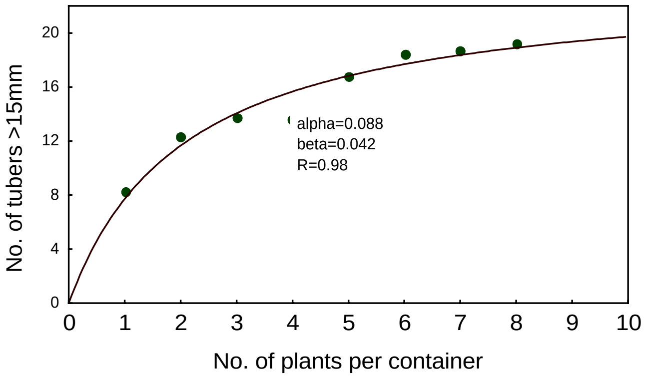

Figure 6 :The effect of planting density on the number of tubers (>15 mm diam) harvested per container from microplants of potato cv. Nicola.

These results indicate that at higher plant densities (4 or more per container) the number of tubers harvested with a diameter greater than 15 mm will be similar from microplants or minitubers. The choice of planting material for protected cropping systems will therefore depend on the relative costs of production of microplants and minitubers.

Outdoor observation with microplants

Microplants of potato cv. Nicola were planted outdoors on July 3 at a spacing of 25 cm in rows 60 cm apart (6.67 plants m^{-2}). The plants were irrigated on July 4 and 12 to aid establishment. Plants were sprayed regularly for control of aphids and blight and were harvested at the end of October. The mean number of tubers harvested with a diameter greater than 15 mm per plant was 8.2

Conclusions

- The results of these experiments suggest that a yield of approximately 15 minitubers per crate (245 per cropped m^2) can reasonably be expected per crop assuming 4 or more tubers are planted per container.
- The experiments have demonstrated the possibility of obtaining two crops of minitubers per year in an unheated greenhouse. It may be possible to obtain three crops but this would require the provision of frost protection.
- Lower plant densities increased the multiplication factor but reduced the number of tubers harvested per unit area. The optimum planting density varies with the cost of the planting material.
- Sprouting the tubers would reduce the length of cropping and may improve the plant stand with small tuber size.

- The cost of peat is an important cost in this system of production. The effect of using reduced volumes should be studied as should different and cheaper types of container.
- The performance of microplants indicated that they give similar results to minitubers. The choice of planting material will depend on the relative production costs.
- Potato microplants can be successfully established in the field in summer. This would be the cheapest method of producing minitubers but protected cropping may still be desirable for effective isolation from virus vectors and to enable multiple crops per year.
- The possible benefit of some form of canopy support should be investigated.

Commercialisation

A minituber production unit comprising 2 plastic tunnels and based on this technology has been built near Ballina, Co. Mayo.

APPENDIX 1

Model for calculating the cost[1] of production of minitubers based on a unit of 33 x 9.8m greenhouse and two crops per annum.

Item	**Cost (£)**	**Cost per crop (£)**
Capital cost of house, flood bed etc.	5,000	500
Crates - 4,240 @35p (16.39 crates per m^2 and 80% use of area)	1,484	149
Peat - 21,200l @ 3.5p		742
Consumables -sprays, fertilisers etc.		300
Return to grower (based on £10,000 p.a. for a 6 house unit)		833
Total costs excluding planting material		2,524
Cost of planting material (C)	0 - 80 p each	
Number of tubers per crate (N)	1 - 8	
Total cost of planting material (TCPM)		C*N*4,240/100
Yield per crate (no. >15mm) (Y) (using mean predictors)	N/(0.096+0.048*N)	
Total yield per house (TY)	Y*4,240	
Cost per tuber produced (pence)	(2,524+TCPM)*100/TY	

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[1] These cost figures are not claimed to be of high accuracy. The model is used to demonstrate the interaction between the cost of planting material and the optimum planting density.

Development Of A Growing Medium Based On Forest Tree Bark

Introduction

Although peat is the principal material in use as a substrate or growing medium throughout horticulture, there is an increasing demand for a non-peat alternative particularly in the retail sector of the UK market. This has been driven by environmental concerns about bog conservation and the desirability of using renewable materials. There are many reports of the successful use of milled forest bark for growing plants but the commercial development of bark substrates has been very slow. Forest tree bark is an increasing resource in Ireland. By the year 2011, bark production from Coillte forests will amount to 370,000 m^3 and production from private forests will be coming on stream.

Before bark can be used as a growing medium for plants, the phytotoxins which it contains must be removed. Bark also contains some relatively easily decomposable components such as cellulose and hemicellulose, which if present in a plant substrate would be broken down microbiologically and would deprive the plant of nitrogen and also lead to a physical degradation of the substrate. To overcome these problems, the bark is first milled and then subjected to a composting process with the addition of nitrogen. After the thermophilic phase of composting, during which the composting stack can reach temperatures over 60^{O}C, and a maturation period, the stabilised material is ready for use.

The aim of these experiments was to develop a plant growing medium based on 100% Sitka spruce bark through first studying the effect of rate of application and source of nitrogen on the composting of milled sitka spruce bark and then optimising the nutrient addition to the composted bark.

Composting bark

Sitka spruce bark, recently hammermilled through a 15 mm screen, was divided into four lots each of 6 m^3 volume (Figure 1). Nitrogen was added to each lot as urea at 0.5, 1.0 or 1.5 kg N m^{-3} or as calcium ammonium nitrate at 1.0 kg N m^{-3}.

The fertiliser was mixed thoroughly and the four heaps were left to compost.

Figure 1:Stacks of composting bark.

The stacks were turned after 7, 14 and 34 days. Samples were taken at intervals and analysed for total mineral content and for available levels of nutrients using both water and DTPA/$CaCl_2$ extracts. The temperature of each heap was monitored twice per day using a squirrel datalogger.

The temperatures in the four composting stacks are shown in Figure 2.Temperature rose sharply in the first four days after mixing to over 70^{O}C where urea was added at 1.0 or 1.5 kg N m^{-3}. Temperatures in these stacks were higher in the first two weeks than the stack with 0.5 kg N m^{-3} as Urea or the stack with CAN.

Temperatures recovered well after the first turning, less so after the second, with the exception of the 1.5 kg N stack. After three weeks, the temperatures were on a definite downwards course so turning was delayed. Recovery of temperature was very slow after the third turning on day 34. The measurements were discontinued after 44 days.

Figure 2 : Temperature of composting bark with three rates and two sources of N

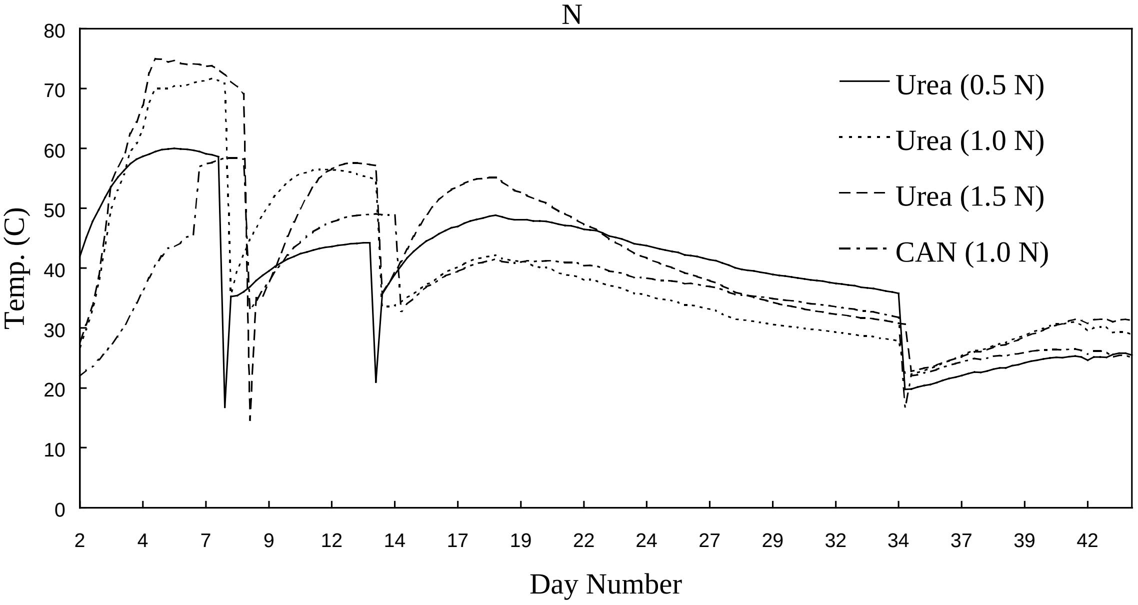

Figure 3 :Tomato plants in a bark growing medium.

Where urea was added to the bark, the pH rose above 7.0 and then declined with time. By the final date, when nitrification had taken place, the pH had fallen below 5.0. The pH in the CAN stack did not change and nitrification had not yet taken place by the last sampling date. EC in the urea stacks tended to be falling over the composting period, in tune with the available nitrogen levels, but rose sharply at the final sampling. The K, Ca and Mg were stable until the last date and then increased dramatically. Levels of available N appeared to be highest at the middle rate of urea addition. This may be due to the fact that nitrification has not fully taken place in the high urea stack and the water extract analysis may be underestimating the NH_4-N.

The DTPA/$CaCl_2$ analysis commenced about one month after composting started. It showed a much less dramatic transition between the last two sampling dates than did the water extract analysis presumably because the DTPA extract was more effective at recovering the exchangeable minerals than is water. NH_4-N levels were much higher than in the water extract analysis and these figures show a fall in total soluble nitrogen levels as the compost matures.

Figure 4 : A healthy root system on a plant growing in bark.

Nutrient addition to composted bark

A series of pot experiments was now carried out, under glasshouse conditions, to study the effect of addition of N, P, K, Ca, Mg and trace elements to composted bark on the growth of plants in the bark, on nutrient levels in the growing medium and in the plant tissue.

The N added during the composting phase usually provides sufficient available N for plant growth in the composted bark. A level of 250 to 350 mg/l in the bark as measured by $CaCl_2$/DTPA extract was the optimum range. If after composting the N level is below this then additional N is desirable.

Additional P was needed to bring plant tissue levels up to the normal range for plants grown in peat substrates. There was no benefit obtained from adding K, Ca or Mg to the composted bark. There was a positive response to supplementation with Cu but not with Mn, or Zn. The addition of Fe reduced the uptake of Mn.

Figure 5 : Commercial growbag containing 100% forest bark.

Plant performance in bark versus peat

In this series of experiments, a commercial peat based potting compost was always included as a control treatment. In all but one of the experiments, the best treatments in the bark growing medium produced plants which were comparable with those in the commercial compost.

Commercialisation

A growing medium based on this work is now being marketed as a retail product by Bord na Mona in the UK under the name Shamrock Peat-Free Multipurpose Compost. This is now in its third year of production

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