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A glasshouse technique (using *Phaseolus vulgaris* L.) to study canopy competition at equal root volume

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Summary

A glasshouse technique is described which avoids interactions between root volume and nutrient uptake. This technique can be used to study the canopy effects among widely different plant spacings and among one or several cultivars.

The technique uses tall thin tubes (pots) for plant support. These tubes allow very close spacing between plants. Continuous nutrient supply promotes growth while constant removal of leached nutrients prevents uneven distribution among plants.

The system was successfully tested by conducting several trials in which navy beans (*Phaseolus vulgaris* L.) were grown at spacings of 36, 225, 400 and 625 cm² per plant. The yield and some yield components are presented. Yields ranged from 266 to 863 g/m² for the low to high plant density respectively.

This testing phase indicated that several important points need attention. Nutrient type and amount for each plant type need clarification. Growth behaviour under non-limiting conditions should be known. Most importantly the whole system should receive maximum protection against disease and insect pests.

INTRODUCTION

Field trials conducted to test the effects of plant spacing on yield are often difficult to interpret. Irrigated trials with navy beans (*Phaseolus vulgaris* L.) at Inglewood (south-east Queensland) indicated little yield increase after increasing plant populations from 125 000 to 250 000 plants per hectare in 70 cm rows, although there was a significant reduction in grain number per plant the higher plant density (Gunton and Evenson 1980).

Interpretation of trials can be made more difficult by factors such as environmental differences among sites and years, unequal root volumes (Stevenson 1967) per plant (hence available water and nutrient inequalities), and differing light interception patterns.

It has been demonstrated, for instance by Angus, Jones and Wilson (1972), that differences among cultivars can be attributed to their canopy structure. However, in field trials using different plant spacing, canopy differences cannot be confirmed where there are unequal root volumes. Puckridge (1968) overcame much of this objection in a glasshouse study by using long narrow tubes as pots. This allowed him to get very close spacings between plants while maintaining equal root volumes.

The aim of this work was to establish a technique to allow cultivar canopies to be compared over a range of plant spacings. Root volumes were equal and growth was not limited by water or nutrient availability.

MATERIALS AND METHODS

Polyvinyl chloride tubes 6 cm external diameter and 38 cm long were used as pots. A fibreglass mesh (flyscreen) base retained the root medium, vermiculite. Filled tubes were placed on 3 cm of coarse sand in water proof trays. These trays were made from marine grade ply and were coated with a bituminous paint.Three drainage pipes were inserted on one side. The trays were slightly elevated on the water input side to allow efficient flushing of any leached nutrients. Constant running water was supplied from three inlets per tray from a central supply pipe.

The tubes were placed in square patterns of different intervals for each treatment (Table 1). They were supported at the top by nylon string stretched between wooden supports attached to the sides of the trays.

Table 1. The effect of plant spacing on navy bean yields and yield components

Spacing arrangement	Mean yield (g)		Nodes per plant	Pods per plant	Grain no. per plant	Weight per grain (g)
	per plant	per m^2				
6× 6 cm	3.11	863.9	11.6	6.2	39.4	0.079
15×15 cm	8.83	392.5	13.9	13.0	65.0	0.136
20×20 cm	12.01	300.2	17.8	15.9	87.0	0.138
25×25 cm	16.60	265.6	17.7	26.9	147.0	0.113

Roots (which grow out onto the sand after several weeks) were shaded initially by polystyrene beads and in later trials by a wooden cover suitability drilled for plant spacing treatment. This latter method also provided rigid support to the tube base.

Nutrients were supplied from an elevated tank, gravity fed via a float chamber (to provide constant head) to a supply line, and finally to a microtube. All microtubes were the same length and were inserted into the top of the tube, just clear of the root medium to allow easy checking for blockages. Flexible hoses at either end of the float chamber allowed it to be raised or lowered to give the desired output to the tubes. This allowed changes in the nutrient feed rate to match the plant demand without changing the nutrient concentration. The nutrient supply line could be flushed via a tap connection near the float chamber outlet. This allowed regular clearance of any algal or bacterial build-up in this line.

Figure 1 outlines the major parts of the system and Figures 2, 3 and 4 show various aspects of the system and its layout.

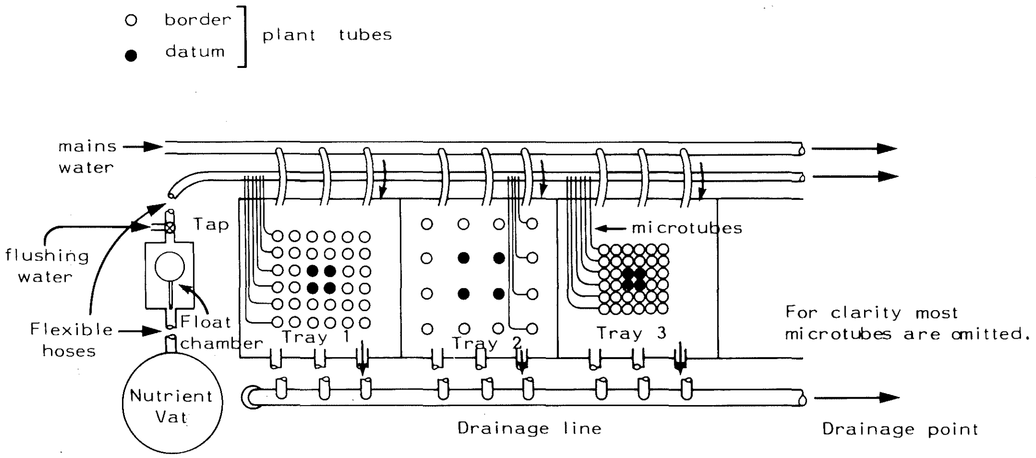

Figure 1. Schematic diagram of system showing different square arrangements.

Figure 2. General view of navy beans grown with the system described. Nutrient supply vats are elevated in the background. Micro tubes and drainage lines are visible. Four square spacial arrays were being tested during this run. Note the marked height increase with closer spacing with unrestricted water and nutrient supply.

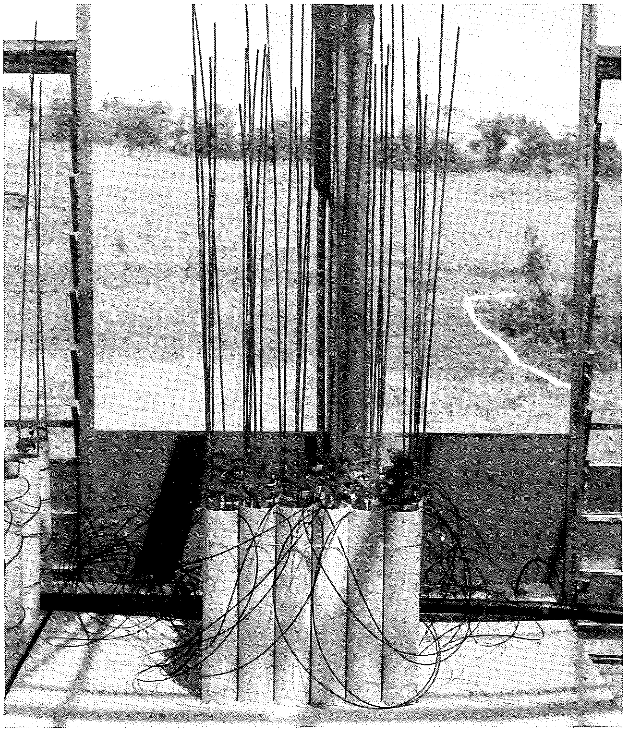

Figure 3. Layout for the closest spacing treatment is shown. Wire spacing restraints are clearly shown. These prevented lodging disruption to spacial arrays. Micro tubes and water inlet lines are also shown.

Figure 4. Here a closer view of micro tube insertion is presented. Young navy bean plants are growing in vermiculite at the closest spacing used. Nutrient droplets can be seen on the end of some of the micro tubes. The rate of droplet output can be regulated by the position of the float chamber. Again the wire spacial restraints are visible.

Operation

A suitable rate (for example 285 mL/day/plant) of dilute nutrient was dripped continually on each tube. The rate was increased to 300 mL when the plants first flowered. The nutrient solution used in these trials was made from a complete soluble fertiliser, Aquasol®. Although it would have been preferable to use a Hoagland type solution, this mixture appeared satisfactory if used as recommended by the manufacturer. A pH test on the vermiculite at the end of the trial showed a neutral reaction. However, the topic of nutrient solutions is more adequately covered in hydroponic articles, for example Page and Barke (1977).

The nutrient supply system was cleaned weekly throughout the trial. Storage tank and float chamber were scrubbed and the supply line and microtubes flushed with town water pressure for 1 h.

Evaluation

Trials were conducted to test this system by growing navy beans (*Phaseolus vulgaris* L.) at different plant spacings in 1973, 1974 and 1975. In the first two years lodging and other difficulties invalidated the yield response data. In 1975 wire rods were used to prevent lodging and other difficulties, especially disease control, were overcome. The yield and yield component data are presented in Table 1. Mean yield was determined from the centre four plants in each treatment (Figure 1).

RESULTS AND DISCUSSION

The technique successfully demonstrated the ability to grow healthy plants at all spacings such that the yields achieved are credible with comparable well grown crops in the field (Gunton and Evenson 1980). The increase in yield was non-linear over the plant spacing trial and is a reflection of the indeterminate growth pattern of the cultivar grown (Selection 46) (Westermann and Crothers 1977). The yield increase at closer spacing was accompanied by a decrease in pods and grain number per plant, and in weight per grain.

The use of the technique during these trials prompted several recommendations:

1. Sterilisation of equipment and root medium to reduce pathogen incidence. Any plant mortality or retardation of growth caused by disease (or insects) severely hampers interpretation of data.

2. Use distilled water to make up the nutrient solution, along with high density black supply lines and tanks etc to deter algal growth.

3. Use a root medium that allows adequate aeration, plant support and nutrient exchange capacity. This medium may vary between species and may vary the nutrient requirements.

4. Provide a deeper layer of gravel or coarse sand under pots to allow efficient flushing of leached nutrients and hence prevent uneven build-up of nutrients among treatments.

5. Examine the growth behaviour of the species in non-limiting conditions so that adequate planning for unexpected problems can be made, for example in these trials the indeterminate habit of the cultivar was exaggerated in height especially at the closer plant spacing and trellis was necessary to prevent the plants lodging.

This technique, which eliminates root volume competition, has been shown capable of contrasting differences among plant spacings. It should be valuable in assessing canopy competitiveness among cultivars.

References

Angus, J.F., Jones, R. and Wilson, J.H. (1972), A comparison of barley cultivars with different leaf inclination, *Australian Journal of Agricultural Research* **23**, 945-95.

Gunton, J.L. and Evenson, J.P. (1980), Moisture stress in navy beans. 1. Effect of withholding irrigation, *Irrigation Science* **2**, 49-59.

Page, P.E. and Barke, R.E. (1977), Hydroponics—growing plants without soil, *Queensland Agricultural Journal* **103**, 480-87.

Puckridge, D.W. (1968), Competition for light and its effect on leaf and spikelet development of wheat plants, *Australian Journal of Agricultural Research* **19**, 191-201.

Stevenson, D.S. (1967), Effective soil volume and its importance to root and top growth of plants, *Canadian Journal of Soil Science* **47**, 163-74.

Westermann, D.T. and Crothers, S.E. (1977), Plant population effects on the seed yield components of beans, *Crop Science* **17**, 493-96.

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