Plant nutrition studies in the classroom

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Hewitson and Price (1994) describe a technique to investigate the effect of substrate nitrogen level on plant yield and biomass partitioning. In their method, individual radish plants were grown in film canisters, in an inert medium, with nutrients and water being supplied from a reservoir of nutrient solution via capillary uptake through capillary matting. Plant growth at nitrogen levels of 7, 14, 28, 56, 112 and 224 ppm was compared, and they found that the plants exhibited a characteristic yield response curve, with diminishing gains from each addition of nitrogen. There was a reduction in total yield in plants grown at 224 ppm N when compared with those grown at 112 ppm N. They also found that nitrogen level caused a change in the partitioning of dry matter between the 'root' (hypocotyl) and leaves of the radish, with plants grown at low nitrogen levels putting a much greater percentage of their resources into leaf growth.

In a growth trial of *Raphanus sativus* 'Short Top Forcing', at BSUC, using the methodology and equipment described by Hewitson and Price (1994), plants in the 112 and 224 ppm N treatments displayed loss of turgidity, chlorosis and necrosis of the leaf margins. This was indicative of a high level of total moisture stress (ψ_T), which was likely to have reduced the potential growth rate and yield of the plants. Total moisture stress is the sum of the osmotic tension (ψ_S) and soil water or matric tension (ψ_M) (Bunt, 1988) and secondary growth trials were set up to quantify the relative importance of these factors. These growth trials utilised a range of growing media. In the nutrient solutions used, ψ_S was highly positively correlated with the electrical conductivity (EC) of the growing solution which was raised by the addition of 2 mol dm^{-3} sodium chloride (NaCl) solution. The only differences in mineral levels, of the nutrient solutions, from those of Hewitson and Price (1984) were the addition of a variable amount of sodium and a higher upper nitrogen level of 293 ppm. The results can be summarised as:

- **The effect of increasing salinity (osmotic tension ψ_S).** When the nutrient content was constant, there were no statistically significant differences in the growth of *R. sativus* 'Short Top Forcing' grown in solutions with electrical conductivities within the range 2800 µSiemens (µS) to 10.2 mS (Tables 1 and 2). *Raphanus sativus* was likely to be tolerant of high salinities, being derived from a wild ancestor (*R. raphanistrum ssp. maritimus*) which shows some halophytic affinities and occurs in maritime plant communities (Rodwell *et al.*, 1999).
- **The effect of increased water availability (lower matric tension ψ_M).** When not constrained by ψ_M, the growth of *R. sativus* 'Short Top Forcing' was highly positively correlated with increasing nitrogen concentration, and displayed a linear response over the range 7–293 ppm.

Table 1 Total mean dry mass data for 3000–10 000 µS treatments (n = 10).

293 ppm N	*3000 µS*	*5000 µS*	*7000 µS*	*10 000 µS*
Total mean dry mass/g	0.51	0.54	0.69	0.60
Stem mean dry mass/g	0.21	0.22	0.25	0.21
Root mean dry mass/g	0.29	0.32	0.44	0.38
Root:stem ratio	1.38	1.47	1.72	1.79

Table 2 ANOVA: Total mean dry mass, all treatments 3000–10 000 µS.

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between groups	0.20	3.00	0.07	0.49	**0.69**	2.87
Within groups	4.87	36.00	0.14			
Total	5.07	39.00				

No statistically significant differences between treatments.

In Hewitson's and Price's original paper, total plant biomass was reduced for nitrogen concentrations above about 200 ppm. Data for optimal nutrient levels for hydroponically grown radishes are not available, but recommended nitrogen levels for NFT tomatoes of ≈ 300 ppm would seem to indicate that nitrogen levels of 200–250 ppm are unlikely to be supra-optimal (Anon, 1984). Additionally, *R. sativus* is a member of the Brassicaceae, which are often found in eutrophic conditions (Mabberley, 1987), and so may be expected to be tolerant of higher nitrogen levels.

A further growth trial was run to find the approximate parameters of the unimodal yield response curve of *R. sativus* to substrate nitrogen level. This experiment again utilised the techniques of Hewitson and Price (1994), but with the following differences in methodology:

- The film canisters were supported on rockwool blocks, immersed in the nutrient solution (Figures 1 and 2).
- The canisters were filled with medium grade Vermiculite®.
- The range of nitrogen levels was expanded to 7–896 ppm N.
- Plants were grown in a glasshouse, under supplementary lighting supplying ≈5000 lux at bench level.

Vermiculite and rockwool were used because of their excellent air- and water-retention characteristics (Bunt, 1988). The amount of magnesium and potassium supplied by the Vermiculite was calculated, and taken into account. The additional nitrogen source used was ammonium nitrate (NH_4NO_3). [■ SAFETY: Ammonium nitrate is an oxidising agent: wear eye protection when handling the solid to prepare the solution.] This allowed the addition of nitrogen, without the addition of any other nutrients. Earlier experimentation had indicated that 100% Vermiculite had sufficient physical stability as a substrate, and its high cation exchange capacity (CEC) would regulate any potentially phytotoxic ammonium levels (Bunt, 1988).

Our results (Table 3, Figures 3 and 4) indicate that, for the growing system described, the optimal level of nitrogen in the growing solution is in the range 500–600 ppm N. This optimum range of nitrogen concentrations is significantly greater than those found by Hewitson and Price (1994). There are some simple statistical analyses of the data in Tables 4 and 5 (page 112).

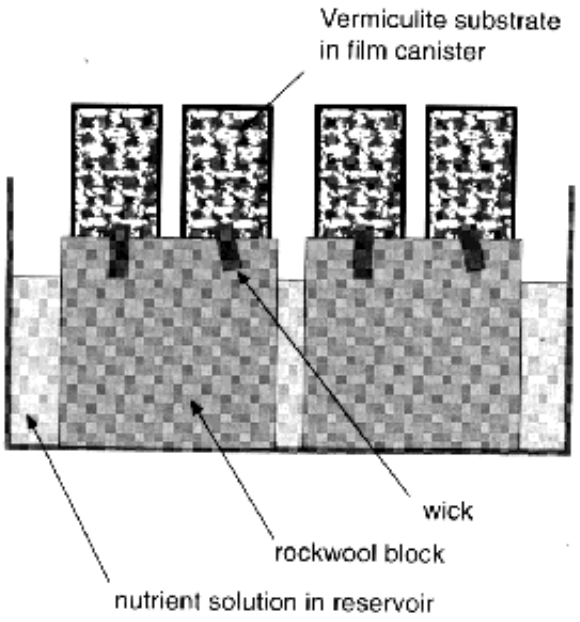

Figure 1 The nutrient culture system – cross-sectional view.

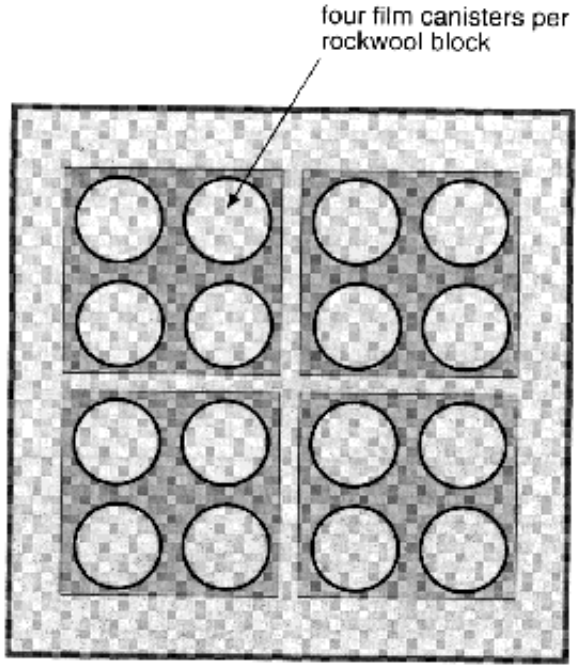

Figure 2 The nutrient culture system – plan view.

Whilst further work is required, it is suggested that the combination of Vermiculite, rockwool and a greater range of nitrogen levels offers an improvement over the methodology in Hewitson's and Price's original article.

Table 3 Mean dry mass data for 7–896 ppm N treatments (n = 10).

Nitrogen (ppm)	*7*	*56*	*113*	*227*	*339*	*451*	*563*	*675*	*787*	*896*
Total mean dry mass/g	0.06	0.15	0.19	0.39	0.56	0.70	0.76	0.66	0.57	0.46
Stem mean dry mass/g	0.04	0.09	0.08	0.17	0.22	0.29	0.27	0.24	0.24	0.22
Root mean dry mass/g	0.02	0.06	0.11	0.21	0.34	0.41	0.49	0.41	0.34	0.24
Stem mean dry mass (% of total)	67%	60%	42%	44%	39%	41%	36%	36%	42%	39%
Root mean dry mass (% of total)	33%	40%	58%	56%	61%	59%	64%	64%	58%	61%
Root:stem ratio	0.34	0.63	1.47	1.23	1.55	1.41	1.77	1.70	1.42	1.06

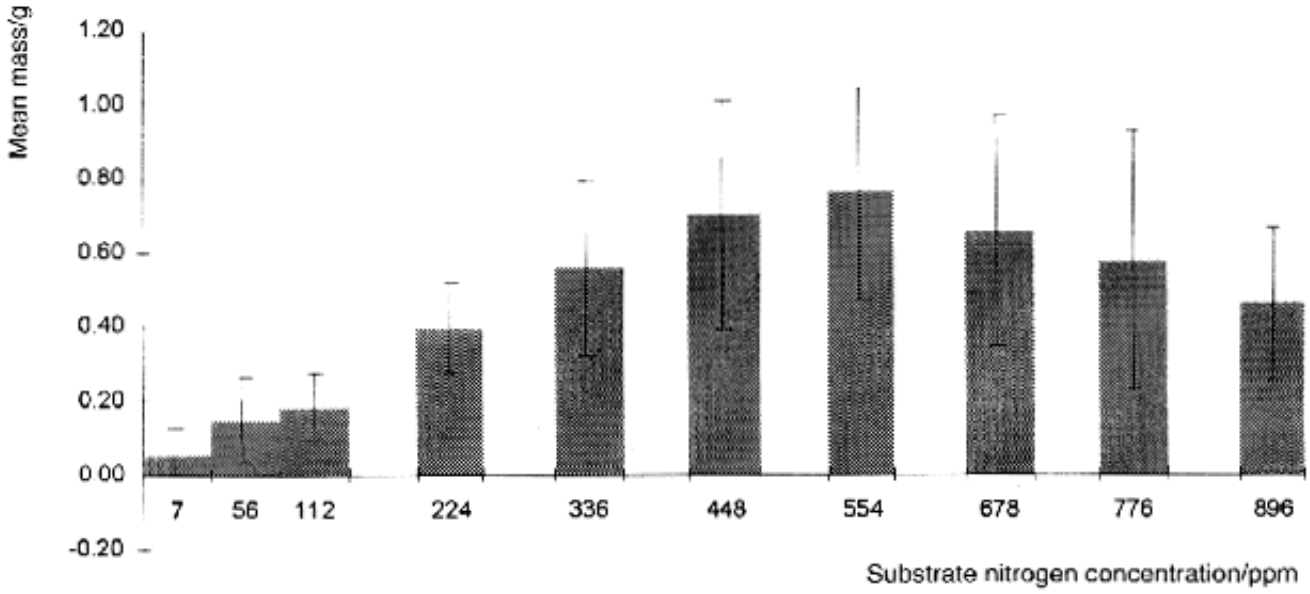

Figure 3 Effect of increased nitrogen on total plant mean dry mass, +/– 1 standard deviation.

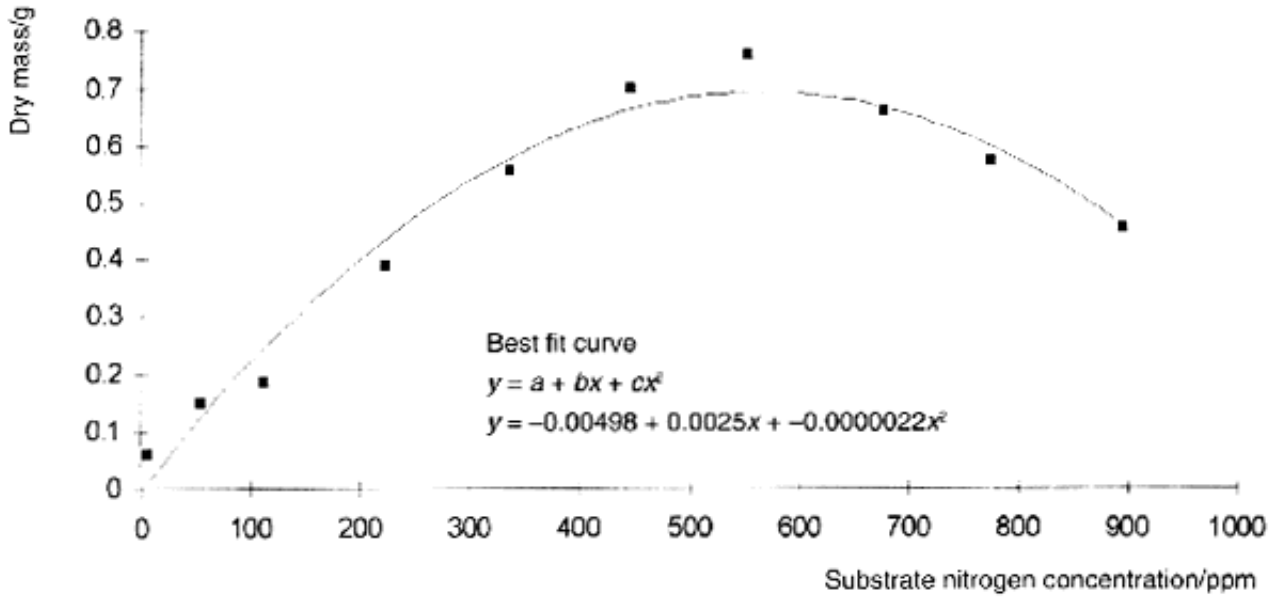

Figure 4 Effect of increased nitrogen on total plant mean dry mass – best fit curve.

Table 4 ANOVA: Total mean dry mass, all treatments 7–896 ppm N.

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between groups	5.44	9	0.604	11.322	**1.16E-11**	1.99
Within groups	4.81	90	0.053			
Total	10.25	99				

Table 5 Total mean dry mass, statistically significant differences – Tukey's pairwise comparison.

ppm N	7	56	113	227	339	451	563	675	787
56	ns								
113	ns	ns							
227	ns	ns	ns						
339	**	**	*	ns					
451	**	**	**	ns	ns				
563	**	**	**	*	ns	ns			
675	**	**	**	ns	ns	ns	ns		
787	**	**	*	ns	ns	ns	ns	ns	
896	**	ns	ns	ns	ns	ns	ns	ns	ns

ns = not significant,
* = significant at the 95% level of probability.
** = significant at the 99% level of probability.

References

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