A Review of Factors Influencing Container-media Temperatures

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INTRODUCTION

Temperature is the main environmental factor determining the release period of encapsulated controlled-release fertilisers (CRFs). Therefore, an understanding of container media temperatures is important to the nursery grower. The aim of this work is to review the factors influencing container media temperature, its effect on plant growth, and to try to establish to what degree various parameters influence the relationship between air and container media temperature. Such an understanding will hopefully allow a more accurate prediction to be made as to container media temperatures based on air temperatures. The latter are more readily recorded and would consequently assist in the estimation of the longevity of CRFs.

FERTILISER RELEASE

Factors such as pH, microbial activity, and moisture levels in growing media have little affect on the rate of nutrient release from a given encapsulated CRF formulation (Sharma, 1979). Different formulations depend on variations in the capsule thickness to provide varying release rates (Rutten, 1980), so that the grower can produce containerised plants for specific periods. The nursery person uses the growing times provided by the manufacturers for each formulation and so a short-term crop may utilise a 3- to 4-month or 100-day material. This nutrient release period is based on a given temperature for each CRF formulation, e.g., 21C for Osmocote and Multicote, and 25C for Nutricote (Lamont et al., 1987; Anon, 1991). Additional information on release periods may be given for other temperatures, e.g., 8-9 month Osmocote will last 10 months at 16C (McPherson, 1994). A local knowledge of media temperatures is therefore important for making use of the advantages of CRFs and to assist in decisions such as when to apply a side dressing. Hicklenton and Cairns (1992) have voiced concern at the way Nutricote recommendations in the U.S.A. tend to be highly generalised and lack specific recommendations for woody ornamentals. Conover and Poole (1987) also point out that release curves developed by manufacturers of Osmocote tend to disregard plant and soil factors in their evaluations.

FACTORS INFLUENCING MEDIA TEMPERATURES

Maximum media temperatures in black polythene bags have been recorded at 49.5C in Auckland, New Zealand (Young and Hammett, 1980). Similarly daily media temperatures can be >40C for up to 6 h and 50C for up to 2 h in Southern U.S.A., and have been recorded as high as 57C adjacent to the container wall (Ingram, 1981; Martin and Ingram, 1988). These temperatures are not necessarily uniform within the pot and will tend to be highest on the east side in the morning and the west side after midday (Ingram et al., 1988). Martin and Ingram (1993) refined this further by showing that the highest temperatures at these two positions on the container walls also tend to be halfway down the profile, regardless of container height (20 to 50 cm) or volume (10 to 70 litres). High temperatures are most likely to occur in black containers where there is high solar radiation. Pot colours that are most similar to black, with its potential to absorb radiation, are most likely to promote the highest media temperature.

MEDIA TEMPERATURE EFFECTS

Of greatest interest here is the fact that high temperatures will influence nutrient release from CRFs. Worrall (1981) found that nutrient release rate from encapsulated fertilisers increases dramatically with temperatures exceeding 35C and concluded that this may occur with surface application. It has also been stated that nitrification can be inhibited resulting in high ammonium-to-nitrate ratios in media (Walden and Wright, 1995). Johnson and Ingram (1984) found that the nutrition of plants was changed at 40C and resulted in reduced K, Fe, and Zn tissue levels but increased N uptake.

Conover and Poole (1985) reported on the effect of full sun (in Florida) on media containing Osmocote having 21 or 32C release curves. Plants with these sources showed that none of the formulations were acceptable unless given 63% shade. In further work by these authors, they state that rapid release of nutrients and possible plant damage may not be as temperature dependent as suspected, and can be strongly influenced by plant size at time of application (Conover and Poole, 1987).

The important end result of high root temperatures is that plant growth will be suppressed as a result of direct as well as indirect temperature effects. Ingram et al. (1986), for example, found that a 40C root temperature regime reduced root growth and increased the shoot-to-root ratio in different species. Keever and Cobb (1984) studied the effect of two pot colours and types of mulch placed on the ground. They found that plants in black pots with a white mulch developed the greatest winter foliage discolouration and leaf abscission and that wide pot spacings (30 cm) were also detrimental.

Much research has shown that root and often shoot growth of container-grown plants subjected to high root zone temperatures is reduced. Spiers (1995) working with two species of blueberry showed that all plants demonstrated a negative linear response to these high temperatures. He found that root and shoot growth were best at 16C and that the two species responded favourably to cultural practices that lower soil temperatures during the summer. Blueberries, like many other plants, have fine shallow roots and there are probably many other plant species that are especially sensitive to high media temperatures. Ingram et al. (1988) conclude that heat injury to roots may result in visual symptoms of water stress, nutrient deficiencies, or lack of vigour. The causal agent of these observed symptoms may primarily be heat stress. These workers showed that the symptoms can be quite strongly influenced by container spacing and that plants at 30-cm centered spacings put on new growth 2 to 3 weeks later than others at closer spacings.

In summary, media temperatures can be influenced by many factors which alter the amount of solar radiation absorbed. Surface covering, container orientation, volume, colour, spacing, and pattern of placement are examples of these. Temperatures in turn will influence nutrient release from CRFs as well as the direct and indirect influences on plant growth. Martin and Ingram (1992) state that the primary environmental factors causing changes in media temperature patterns are solar radiation, wind, temperature, and absolute air humidity. They went on to develop a computer model to simulate the thermal environment in a container. Other factors involved are the differing thermal properties of media and the influence of media water levels (Parikh et al., 1979).

RECORDINGS AT LINCOLN UNIVERSITY

Three studies were carried out to examine media temperature levels in containers. In each study the probes were inserted into the centre of the media of pots with the measuring tip 85 mm below the surface. Air temperature was measured at 1.8 m in an aspirated radiation shield. Temperatures were recorded at 5-min intervals.

Study 1. Media (peat and perlite [1 : 1, v/v]) temperatures of pots containing *Schlumbergera* plants in 2.5-litre (175 mm diameter) brown plastic pots on a 1-m high bench, in a fibreglass greenhouse, were recorded. The mean readings for three media probes, and air temperatures, plus the total hourly solar radiation recorded at a nearby weather station, are shown in Fig. 1. This demonstrated a lag period between media and air temperatures. Another notable aspect was that the air temperatures overnight were 2 to 3C higher than the media figures. This was thought to be due to temperature stratification in the greenhouse at different heights. The air temperatures were recorded at 0.8 m higher than the pot probes. There was on this late winter day quite low solar radiation. This in part was due to the somewhat opaque nature of the fibreglass cladding of the greenhouse. When the sun rose to its highest at noon it caused a peak in the air temperature and a more rounded rise in media temperature which followed. Air and media temperatures also showed a subsequent fall after the solar radiation had declined.

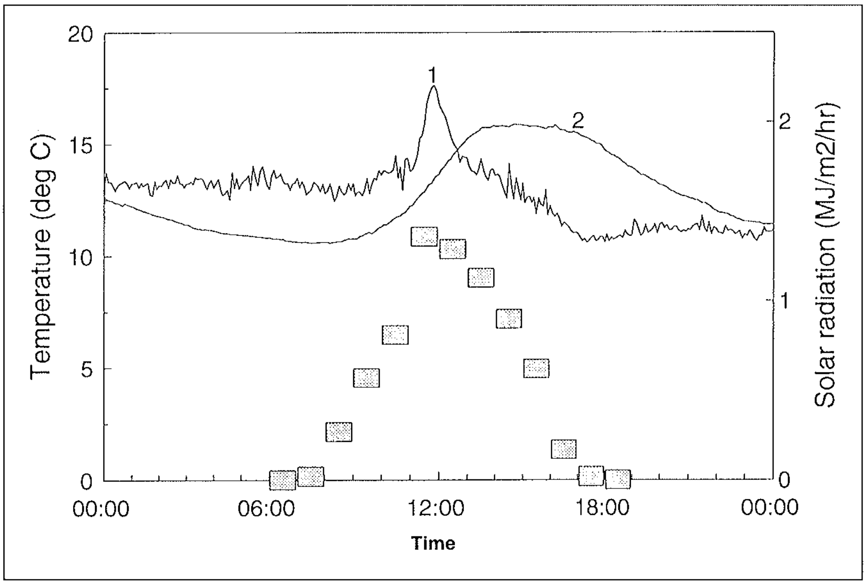

Figure 1. Air temperature (1) and mean media temperatures (2) in a greenhouse and solar radiation (shaded) on 14 August.

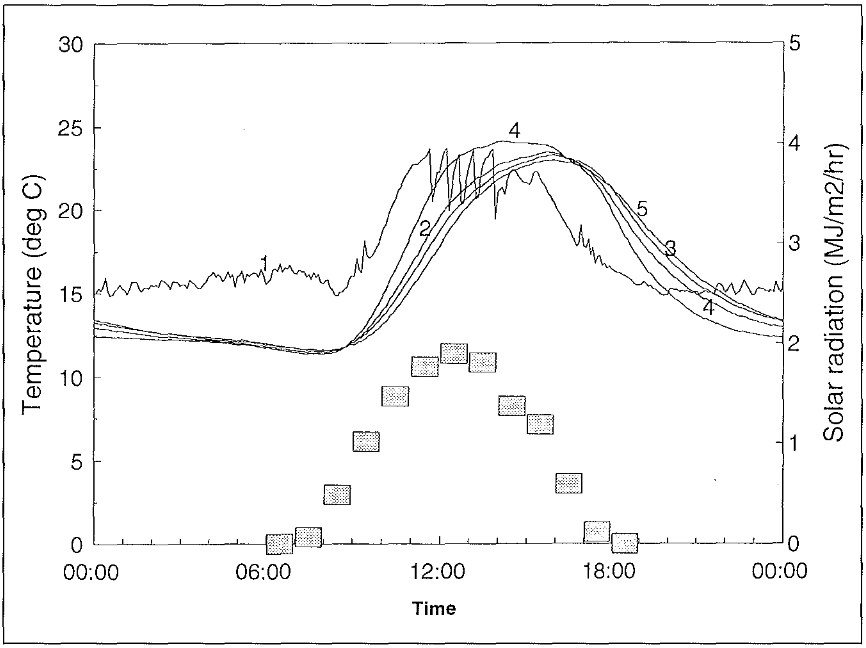

Figure 2. Air temperature (1), and media temperatures (2) bark and sand [4 : 1, v/v], 1.5 litre, 100%WHC; (3) peat and perlite [1 : 1, v/v] 1.5 litre, 100% WHC; (4) peat and perlite [1 : 1, v/v] 1.5 litre, 50% WHC; (5) peat and perlite [1 : 1, v/v] 5 litre, 50% WHC in a greenhouse and solar radiation (shaded) on 19 August.

Study 2. Probes were inserted into five plastic pots as stated in Study 1. In this case the difference was that they contained no plants and had different media, colours, moisture levels, and pot sizes.

Figure 2 depicts the influence of different media, moisture levels, and pot sizes in a greenhouse environment. The influence of the lifting-ridge ventilation system is shown quite dramatically when the air temperature reached a maximum of close to 24C. There was a sudden drop in temperature with cool air replacing hot air. The peat and perlite (1 : 1, v/v) medium heated up most rapidly, especially when at 50% water holding capacity (WHC). The other three treatments appeared similar; namely a larger pot (5 litre instead of 1.5 litre) containing the same medium, bark and sand (b/s) (4 : 1, v/v), and peat and perlite at 100% WHC were all slower to warm up and slower to cool down than the 50% WHC peat and perlite (p/p) (1 : 1, v/v).

The mean figures for the seven days (24-h periods) starting midnight of 16 August were:

Medium	WHC	Pot Volume (litre)	Pot Colour	Temperature (C)
air	-	-	-	17.6
b/s	100%	1.5	black	16.2
p/p	100%	1.5	black	16.3
p/p	50%	5.0	black	16.3
p/p	50%	1.5	black	16.3
p/p	50%	1.5	brown	16.2

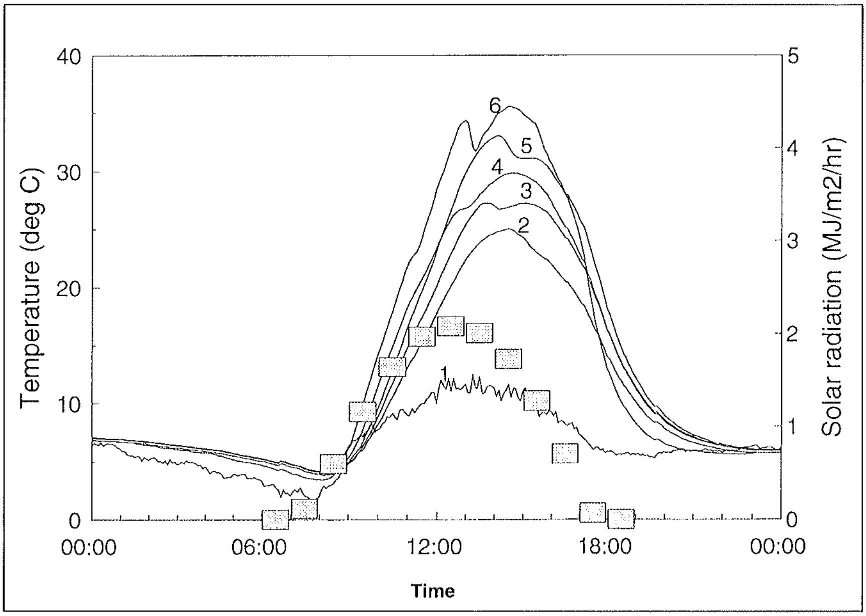

Figure 3. Air temperature (1) and media temperatures in different coloured pots (2) light blue 2.5 litre; (3) brown 2.5 litre; (4) green 2.5 litre; (5) black 2.5 litre; (6) black 1.5 litre outside, and solar radiation (shaded) on 26 August.

The means over these seven days were very similar for all of the pots showing that although some pots increased in temperature more rapidly than others, this was compensated for by faster cooling. The air temperature mean was 1.4C above the media but this may be accounted for by temperature stratification within the greenhouse as discussed earlier.

Study 3. Five pots were again used but they were placed outside on the north end of the greenhouse. They were all 2.5-litre (except for one 1.5-litre black pot) plastic pots and different colours (as shown in Fig. 3). The pots all contained peat and perlite (1:1, v/v) at 50% WHC and were placed 10 cm apart, running east to west, on a 1-m high bench. An additional pot was placed at both ends of the line to act as a "guard pot". The air temperature was measured at 1.8 m.

Figure 3 shows that colour can have quite a major affect on media temperatures. During the day the 1.5-litre black pot heated up most rapidly followed by the 2.5-litre black pot. Media in the dark green, brown (terracotta), and finally the light blue pots reached their maximum temperatures between 2 and 3 PM on this winter day (26 August). The maximum for the small black pot was 10C higher than that of the light blue pot. A dip in the readings towards the peak of the curves is thought to be a small pole which would have given temporary shading. It is also noteworthy that outside in the sun the media temperatures rose between 12.5 and 22.5C above the air temperature. Hourly solar radiation figures have also been plotted on the graph and they confirm the importance of the sun's radiation in heating the pots and media.

The mean temperatures recorded over the 4 days from midnight August 23 were:

Pot colour	Volume (litres)	Temp. (C)
Light blue	2.5	10.9
Green	2.5	12.5
Brown	2.5	11.7
Black	2.5	12.7
Black	1.5	12.6
Air		8.1

Media temperatures for pots outside were much higher than the air temperatures and it was found that colour had a great influence with black pots having the highest mean temperatures.

DISCUSSION AND CONCLUSIONS

In the greenhouse the recorded mean media temperatures were very similar to the air temperature. It appeared that the nature of the media (ingredients and WHC) and pots (volume and colour) had only a small effect on the media temperatures. The greenhouse had a moderating effect on the media temperatures because of the relatively low light levels (approximately 50% of solar light transmittance) experienced. It can therefore be concluded that where solar radiation is low, for example, because of the opaque nature of a cladding material or the application of heavy shading, it is probable that the greenhouse air temperature will give a close indication of media temperatures.

Under these circumstances the media and pot characteristics will have little effect. This would be particularly so when natural solar radiation is lower from late autumn to early spring. From this it would appear that under these conditions recorded air temperatures should give an indication as to the likely nutrient release period of an encapsulated CRF.

In the outside area there were much greater extremes and in fact the air temperature mean was 2.8 to 4.6C lower than the various pot colours. This difference is accentuated by the clear exposure of the pots to solar radiation and compounded further by pot colours which absorb heat to varying degrees. This would be maximised in mid summer in sunny locations and tropical climates or perhaps in an unshaded greenhouse with clear cladding.

The observations carried out at Lincoln University confirm that there can be quite large variations in temperature between pots. Solar radiation is the major factor inducing high media temperatures and it was demonstrated that this influence can even occur in late winter in Canterbury. This is especially likely to occur with black pots. Conversely any form of shading, close spacing, and the use of light coloured pots, all tend to minimise these problems and benefit the plants, as suggested by other workers. The recordings at Lincoln University have shown that greenhouse temperatures, under low solar transmittance, can provide a useful guideline but under high solar radiation, air temperature will probably not help in assessing the media temperature and consequently the nutrient-release periods of encapsulated CRFs. Similar studies repeated in summer would help clarify these conclusions.

LITERATURE CITED

Anon. 1991. Multicote all purpose slow-release fertiliser. Bulletin. Yates NZ Ltd.

Conover, C.A. and **R.T. Poole.** 1985. Influence of fertilizer source, rate, and application method on growth of *Brassaia actinophylla* and *Viburnum odoritissimum*. Proc. Florida State Hort. Soc. 98:82-85.

Conover, C.A. and **R.T. Poole.** 1987. Effect of potting medium temperatures on release curves of slow-release fertilizers in the presence of *Ficus benjamina*. Proc. Florida State Hort. Soc. 100:357-360.

Hicklenton, P.R. and **K.G. Cairns.** 1992. Solubility and application rate of controlled-release fertilizer affect growth and nutrient uptake in containerized woody landscape plants. J. Amer. Soc. Hort. Sci. 117(4):578-583.

Ingram, D.L. 1981. Characterization of temperature fluctuations and woody plant growth in white poly bags and conventional black containers. Hortscience 16(6): 762-763.

Ingram, D.L., C. Ramcharan, and **T.A. Nell.** 1986. Response of container-grown banana, *Ixora* , *Citrus,* and *Dracaena* to elevated root temperatures. Hortscience 21(2):254-255.

Ingram, D.L., C. Martin, and **B. Castro.** 1988. Container spacing treatments influence temperature fluctuations and holly growth. Proc. Florida State Hort. Soc.101:328-331.

Johnson, C.R. and **D.L. Ingram.** 1984. *Pittosporum tobira* response to container medium temperature. Hortscience 19(4):524-525.

Keever, G. J. and **G. S. Cobb.** 1984. Container and production bed mulch effects on media temperatures and growth of 'Hershey's Red' azalea. Hortscience 19(3):439-441.

Lamont, G.P., R.J. Worrall, and **M.A. O'Connell.** 1987. The effects of temperature and time on the solubility of resin-coated controlled-release fertilizers under laboratory and field conditions. Scientia Hort. 32:265-273.

McPherson, D. 1994. Curly Osmocote questions. Carann News. Jan.

Martin, C.A. and **D.L. Ingram.** 1988. Temperature dynamics in poly containers. Southern Nurs. Res. Conf. 33:71-74.

Martin, C.A. and **D.L. Ingram.** 1992. Simulation modelling of temperature in root container media. J. Amer. Soc. Hort. Sci. 117(4):571-577.

Martin, C. A. and **D. L. Ingram.** 1993. Container dimension affects rooting medium temperature patterns. Hortscience 28(1):18-19.

Parikh, R.J., J.A. Havens, and **H.D. Scott.** 1979. Thermal diffusivity and conductivity of moist porous media. J. Soil Sci. Soc. Amer. 45:1050-1052.

Rutten, T. 1980. Osmocote controlled-release fertilizer. Acta Hort. 99:187-188.

Sharma, G.C. 1979. Controlled-release fertilizers and horticultural applications. Scientia Hort. 11:107-129.

Spiers, J.M. 1995. Substrate temperatures influence root and shoot growth of southern highbush and rabbiteye blueberries. Hortscience 30(5):1029-1030.

Walden, R.F. and **R.D. Wright.** 1995. Interactions of high temperature and exposure time influence nitrification in a pine-bark medium. Hortscience 30(5):1026-1028.

Worrall, R.J. 1981. High temperature release characteristics of resin-coated slow-release fertilizers. Comb. Proc. Intl. Plant. Prop. Soc. 31:176-180.

Young, K. and **K.R.W. Hammett.** 1980. Temperature patterns in exposed black polythene plant containers. Agr. Meteorol. 21:165-172.