Mosaic-pattern Stunting

Good nursery managers keep a close eye on their crops for the first hint of something wrong, but diagnosing the true cause of abnormal growth can be challenging. One of the most puzzling growth patterns that I have seen is where individuals or groups of seedlings are severely stunted, but are interspersed with others that are growing normally. This "mosaic" stunting can occur in both bareroot and container nurseries but the cause is quite different for soil or artificial growing media.

Soil. Mosaic stunting has been observed in bareroot nurseries for many years and with a wide variety of species. There have been many different diagnoses for this disorder but they have been difficult to prove because the stunted seedlings often fail to respond to corrective treatments. About 10 years ago, nursery pathologists in the Great Lakes region did detailed study of "scatter pattern" stunting of 1+0 bareroot white spruce seedlings and found that it had a serious effect on nursery production. Inventories revealed that the stunting ranged from 10 to 35% of the crop and that affected seedlings often did not reach shippable size by the end of the season. After careful study, the ultimate diagnosis was mycorrhizal deficiency because normal seedlings were found to have significantly more mycorrhizal root tips than stunted ones.

Similar symptoms were observed with Douglas-fir seedlings in the Pacific Northwest and the same conclusion was reached - mycorrhizal deficiency. The explanation is logical enough. Soil fumigation kills the mycorrhizal fungi so these beneficial microorganisms must then reinvade the treated seedbeds. Airborne spores of ectomycorrhizal (ECM) fungi enter fumigated seedbeds and reinfect seedlings in a random pattern. These mycorrhizal seedlings develop normally and soon grow much larger than those which remain uninfected and become stunted - resulting in the mosaic pattern. Observations have supported this diagnosis as fruiting bodies of mycorrhizal fungi can sometimes be seen in association with the normally-appearing seedlings (Fig. 3).

Mosaic stunting is especially severe with species which have vesicular-arbuscular (VAM) mycorrhizae such as redwood and many hardwood seedlings. This is

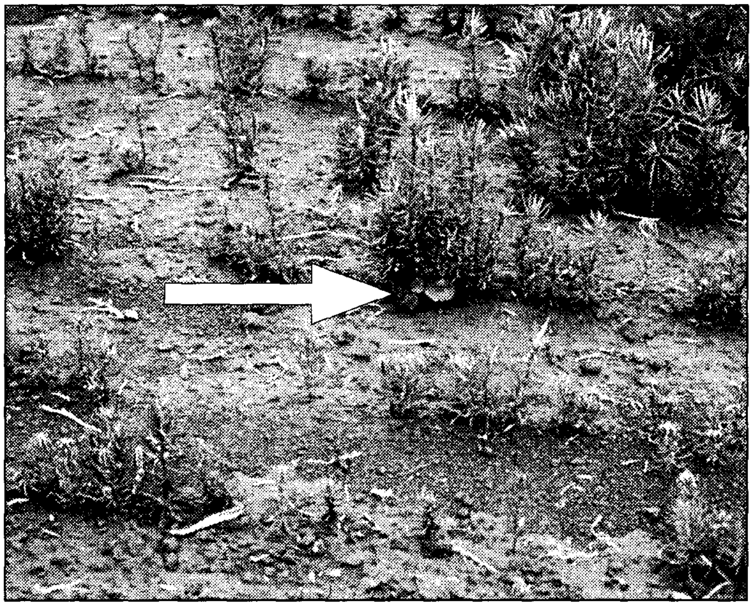

Figure 3. Mycorrhizal fungi make phosphorus available to seedlings but erratic reinvasion after soil fumigation can cause mosaic pattern stunting (note fruiting bodies under larger seedlings.

because **VAM** fungi have relatively large soilborne spores that reinvade fumigated seedbeds very slowly. Unfortunately, the diagnosis of mycorrhizal deficiency has not been confirmed in other investigations of mosaic stunting so there must be more to the story.

A few years ago, I happened to be browsing through an old nursery manual from Great Britain and saw some photographs of "manure" (fertilizer) trials with bareroot Sitka spruce seedlings. One photo in particular caught my eye with because patches of normal and stunted seedlings growing were growing side by side (Fig. 4). The cause for this "patchiness" or "island effect" was phosphorus (P) deficiency. This diagnosis was confirmed when an operational application of superphosphate (0-46-0) fertilizer cured the symptoms.

Reconciling these two diagnoses isn't too difficult as one of the primary benefits of mycorrhizae is that the fungi help seedlings absorb P. This makes sense because young emerging seedlings with small root systems have difficulty obtaining enough P following fumigation unless they become inoculated with mycorrhizal fungi. This hypothesis is further supported by the fact that the stunted Sitka spruce seedlings in the Great Lakes nurseries exhibited purple needle discoloration - a classic P deficiency symptom. Some nurseries have been able to treat mosaic stunting with P fertilizer applications. Timing is critical, however, because the physiological processes leading to stunting take place soon after germination. The limited root system of a germinant is not able to access very much soil and therefore growers should make sure than phosphorus fertilizers are mixed into the top layers of the seedbed. Also, phosphate ions are not mobile in the soil profile so P fertilizers should be applied as an incorporation before sowing. Banding P fertilizer in the zone below the seed is ideal if nurseries have this type of equipment. One easy application method that doesn't take any special equipment is to broadcast P fertilizer on the soil surface, and then mix it into the root zone when the raised seedbeds are formed. Several types of P fertilizer have been effective but concentrated superphosphate (0-46-0) is a good choice. Agronomic research has shown that nitrogen often increases the uptake of P so fertilizers, such as ammonium phosphate (11-55-0), are very effective. Application rates should be based on soil analysis but recommendations typically range from 25 to 50 lbs/ac (28 to 56 kg/ha) of 11-55-0, or 100 to 500 lbs/ ac (112 to 560 kg/ha) of 0-46-0.

Mosaic stunting can also be prevented by encouraging mycorrhizae. Most productive nursery soils contain adequate populations of mycorrhizal fungi but inoculation may be warranted in new nurseries or when new areas are developed for seedbeds. Reinoculation

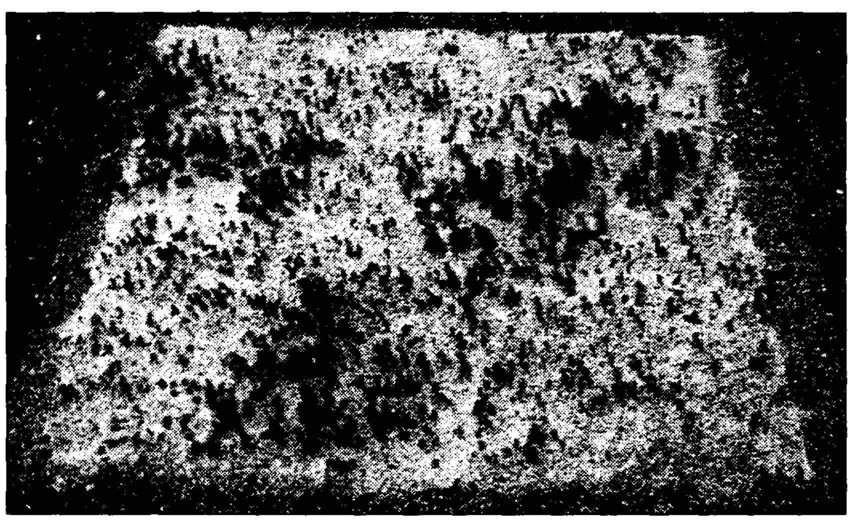

Figure 4. When phosphorus was withheld from these Sitka spruce seedlings in a controlled experiment, they developed a mosaic pattern of stunting which is one of the characteristic symptoms of phosphorus deficiency (from Benzian 1965)

Table 6. Overmixing in a mechanical mixer significantly reduced the size of Sphagnum peat moss particles which can lead to compaction in the container

Mixing Time	Percentage of peat particles in various size classes			
(min)	<0.85mm	<1.18mm	<2.00mm	> 2.00 mm
5	59.4	11.3	11.7	17.6
10	63.8	11.0	8.0	16.6
15	70.2	10.5	7.9	11.4
20	73.5	8.2	7.0	11.3
25	76.4	8.3	6.6	8.7

Source: McDonald (1989)

may also be needed following soil fumigation, especially when growing species requiring VAM fungi. Inoculation options include:

Soil or root inoculum—Incorporating 10% (v\v) of topsoil from beneath known mycorrhizal hosts has been widely used. Since VAM fungi have such a wide host range, some nurseries have grow nurse crops of species such as Sudan grass and then used a mixture of soil and chopped roots as inoculum in fumigated beds.

Nurse seedlings—Transplanting single seedlings that are known to be mycorrhizal is also effective but not practical on an operational scale. Using deficient areas as transplant beds for one season would be more feasible.

Spores-Spores or chopped sporocarps have been successfully used for inoculation of ECM fungi. Spore inoculum also is available commercially.

Cultured inoculum—Many ECM fungi can be grown in pure culture containing vermiculite or other carrier material which can be used as inoculum. VAM fungi also have been grown in pot culture. Vegetative inocula of several ECM and VAM fungi are on the market.

Artificial growing media.
Mosaic pattern stunting also occurs in containers with artificial growing media (Fig. 5). In this case, however, the cause cannot be attributed to phosphorus deficiency or lack of mycorrhizae. Container nursery managers are able to supply their crops with a steady supply of phosphorus, and artificial growing media does not tie-up this nutrient like some soils do. In addition, mycorrhizae are not absolutely necessary during the crop cycle where growers are able to supply all potentially growth-limiting factors. So, the causes of mosaic stunting are different in artificial growing media and there are a couple of possibilities:

Variable compaction of growing media-Porosity in artificial growing media is always critical but especially so in small volume containers. Smaller pores (micropores) must supply seedlings with water and mineral nutrients while larger ones (macropores) provide gas exchange for the roots. Over-compaction of growing media eliminates the macropores which causes reduced growth and eventual stunting. Uneven compaction between individual cells or areas in blocks of containers can result in mosaic seedling growth patterns (Fig. 5). One common cause of compaction is overmixing with

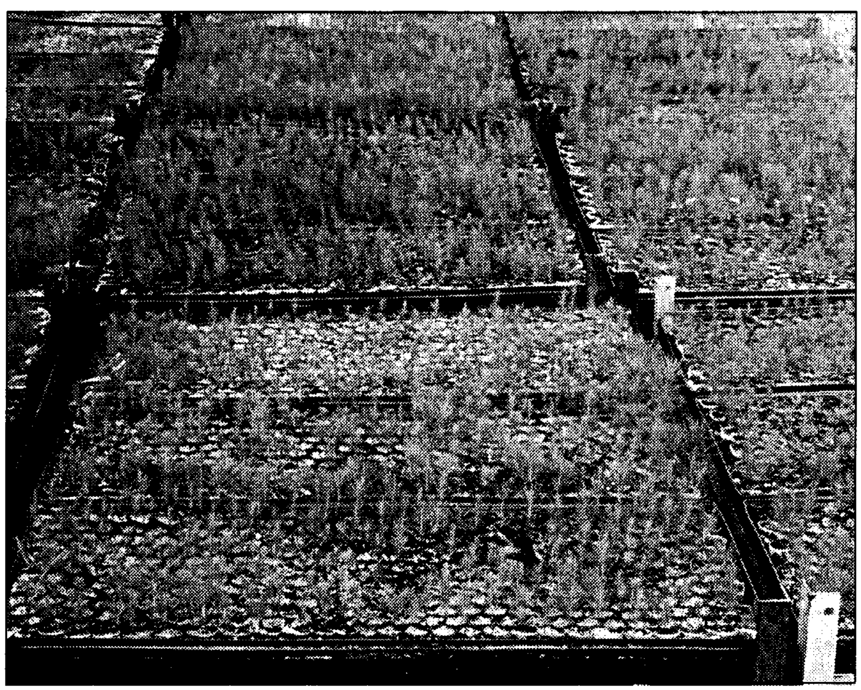

Fig. 5. Mosaic pattern stunting can also occur in containers. In this case, the cause is uneven compaction of the growing medium.

mechanical mixers which reduces particle sizes of fragile growing media components like peat moss and verm iculite. **(Table 6).**

Uneven incorporation of lime or fertilizer - Some growers incorporate "lime" (dolomitic limestone) or slow-release fertilizers into their growing medium before filling the containers. Dolomitic limestone raises the growing medium pH whereas "starter" fertilizers give seedlings a little boost early in the growing season. However, a mosaic seedling growth pattern often results when each cavity does not receive the same amount of limestone or fertilizer. This problem rarely occurs with commercial brands of media because they have specially designed mixing equipment that can evenly incorporate even small amounts of material. It is more common when nurseries mix their own growing medium by hand or with mixers that are not designed for this purpose.

So, in conclusion, these mosaic growth patterns can be puzzling but hopefully these examples will help in their diagnosis and cure.

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