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KEN REISCH: The next paper is prepared by two gentlemen. Dr. Meyer is now at the University of Illinois. Dr. Tukey will present the paper.

NUTRIENT APPLICATIONS DURING THE DORMANT SEASON

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Spring is not the only time for nutrient applications to nursery plants, and it may not even be the best time. However, nursery plants in temperate regions grow rapidly during the spring and early summer. It is only natural to suppose that nutrient applications during this period would be most beneficial, and spring applications are common nursery practice.

However, many workers have shown that nutrients applied to woody plants during the spring and summer often produced no additional growth the year they were applied, but rather were absorbed and stored within the plants. The year following the nutrient applications, important growth differences were noted. Thus, the spring growth of woody plants is dependent to a large extent upon nutrient reserves accumulated in the plants prior to the spring flush (4), that is, during the dormant season. Thus, it becomes obvious that nutrients applied during the dormant season might be effective in promoting a greater amount of spring growth. However, the first question which must be answered is "Do the roots of dormant plants grow during the winter?", for after all, it is growing roots which absorb nutrients.

Therefore, 3 to 4-year-old plants of *Taxus media* 'Hicksii' and *Forsythia intermedia* 'Spring Glory' were grown in a soil peat: perlite medium in 1-qt. plastic containers. After the plants were completely dormant in the Fall, they were placed in a greenhouse in root environment chambers which controlled the root temperature at 35, 40 and 45°F, and the root growth was measured.

The results in Figure 1 with *Taxus* show that there was no measurable root growth at 35°F. However, when the root temperature was increased to 40 and 45°F., there was a considerable increase in the root growth even though the tops of the plants remained completely dormant. In addition, the root growth of plants receiving nutrient applications was much

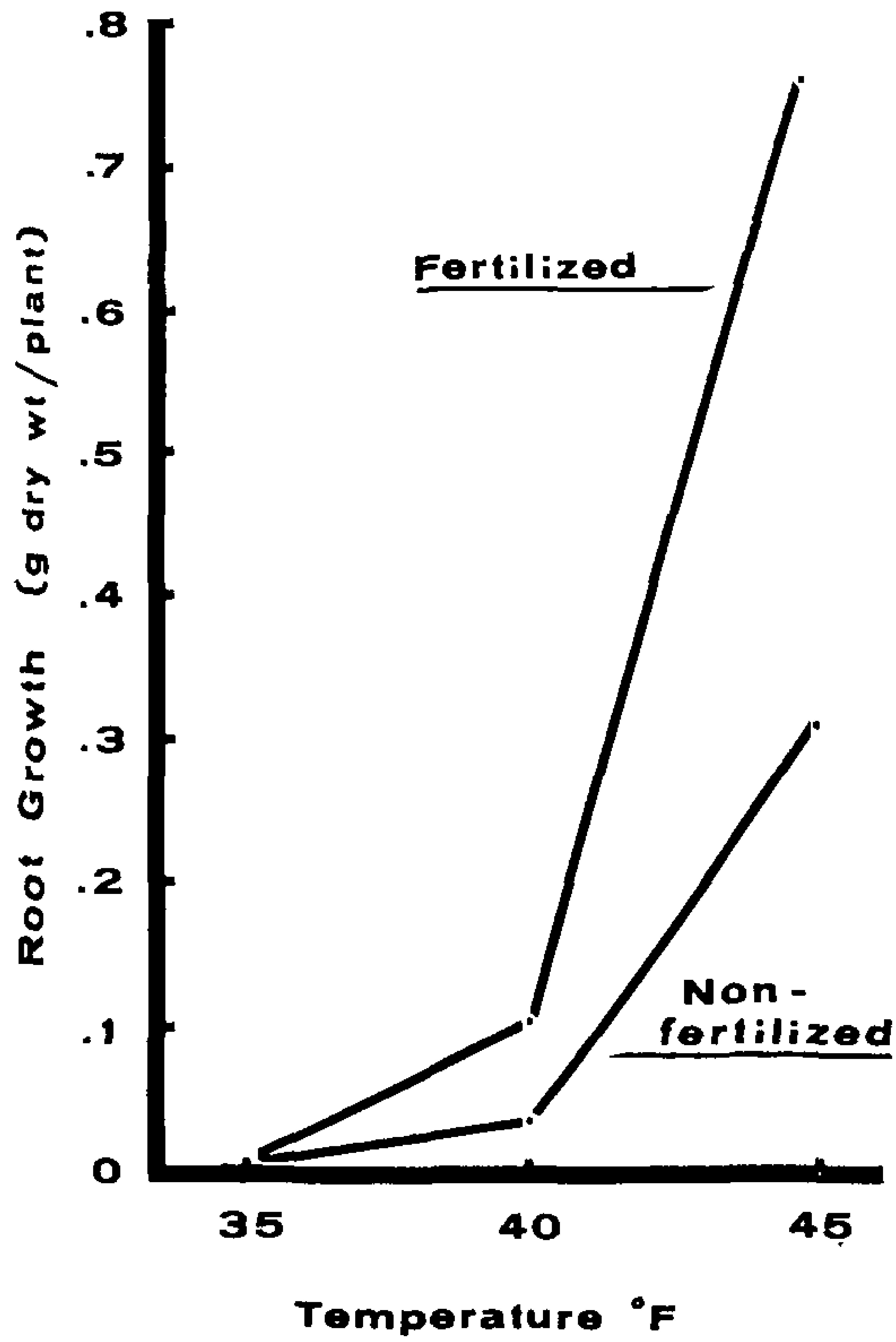

Figure 1 Influence of root temperature and fertilizer application on the root growth of *Taxus media* plants during the dormant season From Meyer and Tukey (5).

greater than that of plants receiving no nutrients. *Forsythia* behaved similarly.

Root growth of plants during the dormant season is now reported in more than 45 species, including fruit trees, shade and forest trees, and ornamental plants. Such growth is usually at a slower rate during the winter than during the summer, but as long as the soil remains unfrozen, root growth will continue.

The next question to ask is if these growing roots can absorb nutrients from the soil and are the absorbed nutrients translocated into the above-ground parts and stored. Accordingly, nutrients were applied to the roots of young *Taxus* plants growing in containers late in the growing season. Nitrogen was applied as NH_4NO_3, phosphorus as KH_2PO_4, and potasium as K_2SO_4 and KH_2PO_4. The nitrogen, phosphorus, and potassium content of the stems and needles was measured in April, while the plants were still dormant, and the results of these analyses are shown in Table 1. As the amount of nitrogen applied to the roots was increased from 0 to 135 milligrams per plant, the concentration of nitrogen in the dormant stems increased from 1.54 to 2.37 percent dry weight. Similar results were obtained with phosphorus and potassium in that increased application rates to the roots increased the dormant season nutrient content in the plants.

In another experiment, Smith (7) reported that radioactive phosphorus was quickly absorbed by the roots of dormant fruit seedlings and was translocated into the dormant stems accumulating in the regions of the buds.

Table 1. Influence of root applications of N, P, and K the previous season on the nutrient content of dormant *Taxus* plants, on the following spring growth, and on the mineral content of new growth.[1]

Treatment	Dormant nutrient content (% dry wt)	Spring growth (g fresh wt)	Mineral content of new growth
Nitrogen (mg)			
0	1.54	19.67	1.49
45	1.95	29.57	1.67
90	2.18	36.50	1.69
135	2.37	38.19	1.77
Phosphorus (mg)			
0	0.157	26.52	0.206
175	0.193	31.46	0.258
350	0.209	34.97	0.266
Potassium (mg)			
0	0.63	30.83	1.04
90	0.78	31.92	1.34
180	0.82	30.20	1.41

[1]From Meyer and Tukey (4).

These results effectively demonstrate that roots growing during the dormant season can effectively absorb nutrients during this period and that the nutrients are translocated into the above-ground parts in preparation for spring growth.

The next question to be answered is, "Are nutrients which are absorbed in the dormant season effective in producing growth the following spring"? The results in Table 1 show that as the nitrogen concentration increased from 1.54 to 2.37 percent, the spring growth almost doubled from 20 grams fresh weight per plant to more than 38 grams. Similarly, phosphorus applications caused an increase from 26.5 grams to 35 grams. New growth was not only stem length, but also an increase in the number of lateral shoots which developed.

Potassium applications did not increase the amount of spring growth of *Taxus,* but in *Forsythia* they did have an influence upon winter injury. *Forsythia* plants which did not receive high concentrations of potassium suffered considerably from winter injury, whereas those which did receive potassium applications suffered no damage. This emphasizes the importance of potassium in the total development of the plant, and it emphasizes the importance of a correct nutrient balance in plants for winter survival.

It is also interesting to note in Table 1 that the nutrient concentration of the new spring growth was increased substantially by nutrient applications the previous season, thus inflencing the potential future growth of the plants.

The results of these experiments and those reported in the literature (1,2,3,6,7,8) demonstrate that fall applications of nutrients are successful in that (a) roots of many woody plants continue to grow in unfrozen soil throughout the winter and do not become dormant like the above-ground parts, (b) these growing roots absorb nutrients efficiently, (c) the nutrients are translocated into the dormant above-ground parts, and (d) are used in making increased growth the following spring.

Fall nutrient applications offer several advantages over more conventional spring applications. For example, soils in spring are wet and cold and may not exceed 35 to 40° in the root zone until the spring flush of growth is well underway. Under such cool soil temperature conditions, the activity of soil microorganisms is inhibited and nutrient availability is reduced. In addition, root uptake of nutrients is also inhibited by cool soil temperatures. Therefore, when woody plants are making their most rapid growth of the year, and when nutrient requirements are at their highest, nutrients may not be available nor be absorbed until too late for that season's growth. And even in the best of years, there is only a critical period of a few days during which nutrients must be applied, carried into the root zone, absorbed, and translocated into the growing regions. Such precise timing of spring applications is often impossible with the pressure of other spring work and land which is too wet to work.

In the fall, it is a very different situation. Cold air temperatures and cultural practices induce dormancy in the tops of woody plants. However, soil temperatures in the root zone remain warm for a considerable period after the tops are dormant. In Ithaca, soil temperatures at the 4-inch depth may exceed 40-45° until well after Christmas, allowing more than 6 weeks after plants are fully dormant during which nutrients can be applied safely and absorbed by the plants. The fall season is often a more convenient time for field work, and fall nutrient applications can be combined with fall herbicides treatments. Fall nutrient applications made after plants are fully dormant will avoid any risk of winter injury, and in fact, there is good evidence that winter hardiness is improved by such applications.

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KEN REISCH: Last but not least, certainly, is a subject that is receiving a lot of attention now, particularly in other parts of the country and other industries, is fertilizer injection systems. To present this is Dick Bosley, Mentor, Ohio.