DR. CLARKE: Could you describe xylosma briefly?

DR. HACKETT: It's a shrub. It can be used as a wind break or a shield and is used to a large extent along freeways as a baffling. It is propagated in quite large quantities in southern California.

MR. JOLLY BATCHELLER: I have an experience that might relate to this propagation. My associate took home two five-gallon cans of Xylosma. He put them on the north side of the house and forgot about them for a while. There was a cold spell and they practically defoliated. He brought them back into the greenhouse and they started to leaf out, so he decided to make hardwood cuttings just as they started to grow. He got around ninety percent. I can't tell you whether he used mist, or the media, or whether he used hormone.

I found it true with Fatshedra which roots very easily anyway, but bring this in out of the cold in the greenhouse for a week before making cuttings, you can make single eye cuttings. You get ninety-nine percent.

THE ROOTING OF MONTEREY PINE

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In 1929, J. F. Field stuck branches from nineteen-month-old Monterey pine in the damp, sandy soil in a New Zealand nursery. He found that they produced a large amount of callus in three months and rooted in five months, with roots as regular as those of seedlings. While he made no accurate count, he claims to have achieved at least 95% rooting on this first major attempt to root Monterey pine. These rooted cuttings were four inches tall in 1929, and averaged twelve feet tall in 1934 when he reported his studies in the New Zealand Journal of Forestry.

Based on Field's success, the Australians began rooting Monterey pine on a large scale. M. R. Jacobs reported on his extensive studies in the Australian Capital Territory in 1939. He predicted that 80% rooting success was possible with six-year-old trees, although few of his reported experiments reached this level of success. Like Field, he relied on an open nursery with little protection beyond maintaining the soil moist by watering.

J. M. Fielding reported on continuing Australian operations in 1954. Several of his reports mention rooting percentages in excess of 90%, although most of his data is in the range of 50-80%.

This by no means exhausts the list of foresters who have rooted Monterey pine with disarming ease and great success. It is time, however, to get around to me and us. "Us", who find ourselves here in a session devoted to difficult-to-root species

(which seems to be a reverse kind of progress), and "me", who seems to be the only forester in the business who is having difficulty rooting Monterey pine.

Unlike the Australians and New Zealanders, we decided to root in a greenhouse, using intermittent mist. The cuttings were collected in five trips, during the period 11 November to 28 December, 1962, from the three native stands of Monterey pine at Ano Nuevo, Monterey and Cambria. They were held in cold storage for varying periods of time (two days to three months). Nine cuttings (with a few exceptions) were taken from each of 540 trees growing in the wild. An equal number of cuttings in each clone was given one of two auxin treatments, or was untreated as a control. The age of the wild trees varied from two to nine years, with a few trees from ten to seventeen years being included in collections from State Parks where young trees of adequate size were scarce. The trees varied in vigor from rapidly-growing trees occurring in openings to slow-growing suppressed trees in the undisturbed State Parks.

We at the University were primarily interested in sampling the total variation of Monterey pine as it now occurs in the natural stands for further genetic studies. We have used random procedures, which got us the sample of 540 clones we wanted. However, these procedures produced a pretty strange-looking experimental design for evaluating rooting. Therefore, my comments today are going to be more in the line of relating our experience to date, rather than any rigorous hypothesis testing. A more critical and complete statistical analysis of the data is in progress, and will be submitted to *Forest Science* in the near future.

Our period of field-collection was in the middle of the season, if you add six months for the change of hemispheres, suggested by Jacobs and Fielding as the most effective time for collecting Monterey pine cuttings. During this period, the trees are fairly dormant (Monterey pine never really gets dormant), just prior to the first big spring growth flush which normally occurs in January. The data on date of collection is confounded with the geographic origin of the clones, their subsequent length of cold storage, and the rooting environment once they finally did get into our rooting benches. In spite of this confounding, a few observations may be worthwhile.

First, we did not do nearly as well as the people Down Under say we should be able to do. Our maximum rooting percentage for one of these collection dates was only 57.6%, while our minimum was 43.1%.

Second, there is not really much difference in the final rooting percentages between the five collection dates. However, cuttings from the 22 November and 8 December dates not only ultimately rooted a little better, but seem to have reached just about their total rooting by the thirtieth week in the bench, as compared to the one later and two earlier collections which

rooted more slowly, and continued to root in appreciable numbers through the fortieth week in the bench.

Cuttings from Cambria rooted better than cuttings from Monterey, which in turn rooted better than cuttings from Ano Nuevo. However, cuttings from the 8 December collection, which rooted best, and cuttings from the 27 December collection, which rooted worst, are both from the Monterey population, and are essentially random samples of that population. Therefore, I think we may suspect that the geographic origin, or native population, of the cuttings is not primarily responsible for the differences in the raw data associated with the rooting performance of cuttings from the different populations. It is more likely that the confounding date of collection, length of cold storage, or subsequent rooting environment account for most of the differences observed. This by no means indicates that there are no differences between the three populations of Montrey pine. It merely says that this data is not sufficiently good to prove it one way or the other.

Throughout the sampling period, we kept records on the length of time the cuttings were held in cold storage (38° F). There is no clearly-defined trend of final rooting percentage associated with storage time. However, those cuttings stored 20 or more days had a major rooting surge in the 21-30 week period after being placed in the rooting bench, while those stored less than seven days fell behind during the period, then closed the gap during the following ten weeks.

Besides percentage of cuttings rooted, I think we are interested in the quality of the rooted cutting, and to a degree that quality depends on the number of roots that we get on a cutting. It appears that cold storage of about 20 to 50 days may be beneficial in terms of number of roots produced, although this observation must be cautiously interpreted due to the confounded nature of the data. Storage of less than 20 days, or 50 to 90 days, seems to allow the cuttings to perform at least as well as unstored cuttings. This we may at least conclude that cold storage of periods up to, and perhaps beyond, three months is possible with Monterey pine without damaging the cuttings, and that such storage may be in some ways beneficial.

Fielding and Jacobs both report that the age of the tree from which the cutting is taken has an important effect on rooting, as one would expect from the general rooting literature. Fielding mentioned 88% rooting from 3-year-old trees, 68% from 5-year-old trees, and only 11% from 26-year-old trees. We have a younger age range, but do have a clearly-defined downward trend of rooting percentage with age. It moves from about 58% rooting for 3-year-old trees down to about 46% for 9-year-old trees. There also seems to be a downward trend in the number of roots per rooted cutting with increasing age of the parent tree, running from an average of about four roots per rooted cutting for young trees 2-to-3 years old, to about three roots per rooted cutting for sapling trees 7to-9 years old.

We were also interested in what effect the apparent vigor of the parent tree would have on rooting. We defined vigor simply as the height of the tree divided by the age of the tree. We suspected that this would be a rather different number for young trees as opposed to older trees, so we arbitrarily split our data into three age groups: 2-4; 5-7 and 8-plus years old. This analysis indicated that young trees outroot older trees, even if they are growing at the same average height per year. It further indicated that the more vigorous trees clearly are not better rooters. If anything, there is a slight downward trend in rooting percentage with increasing vigor. I expected that, since more vigorous trees generally had bigger cuttings, these cuttings from the vigorous trees would produce more roots per cutting. However, the data seems to indicate no relationship of roots per rooted cutting to vigor of the tree.

All cuttings were recut after storage, and vertically scarred for a distance of about ½-inch from the bases with razor blades. Three cuttings from each clone were given no auxin treatment. Six cuttings from each clone were given a 5-second dip in 4000 parts per million indolebutyric acid in 95% ethanol. Three of these six were given an additional treatment of Hormodin #2 powder, applied while the cutting bases were still moist from the IBA liquid dip. These three treatments were randomized within each clone. and immediately placed in the rooting bench. Since all cuttings within a clone received identical treatment prior to and after the auxin treatment, comparisons of rooting performance related to the two auxin treatments and the control are unbiased by the possible confounding factors discussed above.

The IBA quick-dip consistently rooted better than the IBA quick-dip plus Hormodin powder, which in turn consistently rooted in higher percentages than did the untreated controls. The IBA quick-dip alone produced about 20% more rooted cuttings than the controls. Of perhaps as more interest, the IBA quick-dip cuttings tended to root faster than did the controls, and at 20 weeks in the rooting bench, were rooting at 150% of the control rate.

While the IBA plus Hormodin did not root in as high percentages as the IBA alone, this combined treatment consistently produced more roots per cutting than did IBA alone, which in turn produced more roots per rooted cutting than did the controls. Furthermore, it was frequently observed that roots on the controls were thin, as compared to the heavier roots which were typical of the auxin-treated cuttings (Figure 1). I don't know if one or the other of these types of roots is preferable for a rooted cutting, but if it turns out to make a difference, this point may be worth more attention.

In all comparisons where roots per rooted cutting was scored against time in the rooting bench, the cuttings which rooted prior to the twentieth week in the rooting bench maintained a relatively high average number of roots per cutting (about 3 to 4½). However, with increasing time required to

root beyond twenty weeks in the rooting bench, a considerable downward trend developed in the average number of roots per rooted cutting. It may be that the slow rooters begin to run out of nutrients or other factors which increase number of roots. Or, it may be that slow rooters, by the very fact of their being slow, were less capable not only of rooting, but of producing high numbers of roots.

We in forestry consider that a symmetrical root system is important, both in terms of giving us a cutting which is somehow more comparable to that form taken on by a seedling, and in terms of the ultimate health of the tree. In order to develop this type of root system, we grow our rooted cuttings in peat pots. After putting the rooted, potted cuttings through a hardening period to wean them away from the mist, we hold them for an additional month or so before planting them. During this period, the roots continually come through the pot, die at the tips, and regenerate behind the pot edge inside of the pot, resulting in a more-or-less symmetrical root system when we finally plant the tree, (Figure 1). Monterey pine, as you may

Figure one: Left: Cutting with several roots. The tips of the roots were cut off about two weeks before this picture was taken. Note vigorus regenera tion of secondary roots, restricted to roots which had previously develop·ed from the cutting. Center: Single thick root, frequent in both auxin-treated cuttings and untreated cuttings. Further initiation of roots from the cutting after a root has attained this size is rare, if it occurs at all. If an asymmetrical root system is to be avoided, this root must be pruned so that secondary roots from this root form the main system at the time of planting. Right: Thin root frequently observed initiating from untreated cuttings, but rare from auxin treated cuttings.

Figure two: Top row: Plants of seedling origin. Bottom row: Plants of cutting origin. These plants alternate in a row, and average about one meter in height two seasons after outplanting.

know, has an extremely high root regenerating potential, and is capable of regenerating roots behind such dead or cut ends at almost any time in its development and in almost any season of the year.

Finally, it is of some interest to know if and when cuttings become comparable to seedlings, or if not, in what ways they are different. Figure 2 presents three typical cuttings and three seedlings alternated with them and planted the same day. After two growing seasons, the cuttings seem more open, but otherwise are difficult to tell from seedlings. Experiments are planned to compare development patterns in cuttings and seedlings more critically.

DONALD STEELE AND DARA EMERY: Why grow the pine from cuttings when you can grow it so easily from seeds.

DR. LIBBY: We would like to grow the best trees, which may be most effectively accomplished by vegetative propagation. We should also like to use this procedure for studying

genetic variation over a range of environments. Vegetative propagation will increase the efficiency of ecological and other types of experiments by getting rid of extraneous sources of variation. Another reason is that we think we are going to get some sexual precosity from rooted cuttings and can therefore establish a clonal orchard with small trees for seed production. There is some indication that rooted cuttings give better form from a timber point of view than seedlings of the same genotype. There is also some indication (and there is conflicting evidence on this) that we get reduced animal damage. The Australians actually find they get preferential grazing from sheep and rabbits on rooted cuttings as opposed to seedlings. Along the north coast region of California, we have observed a strong preference of deer for seedlings over rooted cuttings.

JACK BARRINGER AND BILL CURTIS: What is the best method to use in rooting the true firs and douglas-firs?

DR. LIBBY: With the true firs you have to pay some attention to what kind of branch you are taking to avoid problems of its thinking it is still a branch many years after you have rooted it. I have seen some very satisfactory trees fifteen or twenty years old from rooted cuttings which for all intents and purposes look like seedling trees. I would suggest you write for the work of Dr. Griffith, who is on the faculty of the University of British Columbia, Department of Biology. He has done some work on douglas-fir in the past with considerable success. Some work is currently being done at the Institute of Forest Genetics, so I pass the buck to Stan Krugman.

STAN KRUGMAN: Well, we are primarily in the propagation of pines. In the past five years we have started the propagation of fir. They can be propagated. They root better from younger sources of material but we have propagated from hundred-year-old trees that fell over by rooting from different parts of the crown. Those from the upper part (the very tips) of the crown will give you suitable plants if you are willing to go up eighty or ninety feet to get them. The same way with douglas-fir. You do not get enough material for mass production. Some things we are working on is bringing down suitable material from tops of trees and grafting it on to younger rootstocks. A couple of years after the union has taken, we propagate from those and increase rooting. Again with the true fir, they may behave as if they are from lateral branches. There is a limit to what you can do with this type of material.

R. H. KNOWLES: How acceptable is the leaf bundle cutting procedure? What is the method for propagating pine species?

DR. LIBBY: Pine leaves come in bundles of usually more than one, and this bundle is morphologically a short shoot. It has a meristem in it as you would have every reason to expect, that given the right treatment, this meristem might produce a shoot. These leaf bundles do, in fact, produce an acceptable plant. There are some tricks to it, however. The most impor-

tant trick is not to get roots on these things, but getting the meristem to break after you get the root. I think the best way around this is to get the meristem to develop into a larger bud before you take the bundle off the tree. This means some kind of mutilation of the branch, in general between three months and a year ahead of the time you want to take these short shoots off. One obvious advantage is that there are a lot more needle bundles on a small tree than there are branches. The other advantage is harder to prove, but frequently these meristems show juvenile characteristics when they break from one of these needle bundles. They have primary needles instead of secondary needles and other characteristics that behave in a juvenile manner. This apparent reduction in physiological age, whatever this is, may make them easier to root. One other piece of advice: some of these meristems, instead of just developing a bud will immediately develop a shoot. Then you're dealing with a shoot like any other, and the advice is to let it harden off. Don't try to root it like a short shoot, but let it go eight or ten months on the trees before you try to take it off and root it.

IVAN STRIBLING: Do you believe seedlings grown from seed gathered in the Monterey area produce a better strain of Monterey pine seedlings than seed from the other two native stands?

DR. LIBBY: We have three native populations of Monterey pine in California, one near Santa Cruz, one in San Luis Obispo County, the other in Monterey. I am going to give you five answers to this question. The first: I don't know. The second: This would depend on the use you intended for it; perhaps a Monterey tree might be better for timber while a Cambria tree might be better for ornamental purposes. The third: Australian tests indicate that the Cambria origin seedlings are not quite as good as those from either Ano Nuevo or Monterey for timber purposes. They don't grow quite as fast or quite as straight. The fourth: I suspect that within-population variation will prove to be greater than that between-populations. This "better strain" will probably be drawn from the better genotypes of all populations. The fifth: This is the question that is asked in our current research and I believe we will have better and better answers on his as the years go on.

DR. KRUGMAN: What about the position of the cutting in the tree, actual age versus physiological age?

DR. LIBBY: The best guess is that the physiological condition varies quite remarkably within a large tree. Some of these differences that would affect rooting, I suspect, are such things as vapor tensions, mineral and carbohydrate nutrition, and hormones. You would expect the morphology and anatomy of shoots in different parts of trees to vary, which may also affect rooting. Relative to Monterey pine, the advice is to use lower branches which have recently originated from either the tip bud on a major branch or those immediately lateral to it, in other

words, first or second order branches of lower branches. We haven't tested this.

PROPAGATING EUCALYPTUS FROM CUTTINGS

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The selection of evergreen shade trees for southern Arizona is limited due to temperature extremes between winter and summer. It is not unusual for temperatures to range above 100°F. in July and August, and there are instances when the temperature will go above 110° F. accompanied by low humidity and hot dry winds. At the other extreme, winter temperatures will drop below 20° F. and remain at this low level for several hours. Survival of trees under these extremes of temperature is limited to a very few specimens including *Rhus lancea,* Olive, Pepper tree and Eucalyptus.

Eucalyptus rostrata and *Eucalyptus polyanthemos* represent two species which are in widespread use throughout the lower elevations of southern Arizona. They survive the environment conditions just mentioned, but there has been observed a noticeable change in the appearance of tree shape and foliage characteristics of trees growing in home yards and in parks.

Landscape architects have indicated a need for eucalyptus of uniform characteristics to achieve the desired effect of uniformity in their landscape plantings. Nurserymen have also been aware of the need for more uniformity in the growth habits of eucalyptus, but their experience with the rooting behavior of these trees have made it uneconomical to propagate them vegetatively.

The Horticulture Department, University of Arizona, initiated vegetative propagation studies several years ago and observed some erratic rooting behavior of the *Eucalyptus rostrata* and *polyanthemos*.Cuttings taken from trees showing any indication of iron chlorosis did not root regardless of treatment used. There appears to be some clonal resistance to iron chlorosis as evidenced by photos taken of a planting of eucalyptus in one of our city parks in Tucson. Poor rooting was also experienced with cuttings taken from older trees ranging 10 years or older, regardless of the type of wood used for cutting material. A higher percentage rooting was obtained from younger trees but this presents a problem to the propagator since he cannot evaluate the desirability of these young trees at the time the cuttings are taken. This would necessitate propagating a number of cuttings from outstanding, individual young trees to serve as future propagating material if the parent trees developed desirable characteristics.

Cuttings taken from sprouts developing at the base of the trunk of old trees rooted as well as cuttings taken from young