VARIATION IN PLANT ROOTS

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Plant root systems are the neglected child of botanical and agricultural research. A considerable amount of knowledge is available about their physiology and anatomy, but nothing about their genetics. What is more distressing is that only little attention has been paid to root systems by the plant breeder during his attempts to improve yield, quality, or horticultural characteristics. In many ways this is only natural since roots are to be found almost entirely below ground, and the amount of effort required to obtain an estimate of the overall size and development of an intact root system is prohibitive.

On the other hand plant breeders have been phenomenally successful in developing varieties which produce root systems comparatively far advanced over those of 15 to 20 years ago. This type of improvement has often not been accomplished by direct selection but rather through a very indirect system called variety trials. Only those varieties which can adapt to the greatest variability in soil environments will give consistently high yields and maintain their quality and horticultural characteristics over several years and greatly differing regions of the country.

To what extent is directed breeding for root characters possible and what are the characters to be selected for? The first part of the question can be answered here, but the second part will differ with every different species of plant and the area it is to be grown. Considerable amounts of research are necessary before we can begin to put the answer into any concrete statements of what to look for or even exactly how to look for it. Sessions like the one on root rots will ultimately be able to clarify some of the more desirable characteristics.

A surprising amount of information may be acquired about any plant's root system by simply taking a single shovel full of soil which includes the base of the plant and its attached root system. Examples of the amounts of information available in this way are the results from a 1970 survey of a tomato variety trial. Tomatoes, and most solanaceous plants, develop a fibrous root system, in addition to their primary root system, in response to damage to the primary root system if the roots are not able to provide adequate supplies of nutrients to the shoot and fruit. This becomes a distinguishing character for determining the relative health of the root system and its ability to adapt to its current environment.

The field for the 1970 variety trial had rows running from east to west approximately 1/2 mile long. The east end was a heavy clay soil and the west, a sandy loam; in middle season the field was over irrigated, drowning some plants on the east end. Tomatoes of the 145-7879 variety demonstrated extensive fibrous root development on the east end with predominantly tap root without fibrous roots on the west end. The sibling variety cv. VF145-513, (it differs from 7879 only by several generations of selection from the original line) showed much less fibrous root development and even had many roots at the extreme east end totally without fibrous roots.

Thus, it can be seen that very similar varieties have extremely different responses to the same root environment as measured with one shovel full of soil and roots. After surveying several variety trials over several years, the conclusion is reached that no two varieties, regardless of their relationship, respond to the environment in an identical manner. Indeed with a little experi-

ence it is possible to distinguish varieties on the basis of their root morphology. Numbers of secondary roots, the dominance of the primary root, direction of root development (vertical vs. horizontal), all differ among varieties and remain consistent differences in differing environments. These all must be assumed to be genetically controlled and therefore accessible to manipulation by plant breeders.

I have been using tomatoes as an example, but the same story holds for variation among varieties of beans and peas. A number of bean and pea breeders have noted root differences, especially in wild or isolated accessions. It is not really unreasonable to expect that any root type found in one legume can either be found or induced in any other legume. But let's look at the total variability possible in root systems. Is it anywhere near that found for the shoot and fruit characters?

The use of mutagenesis and selection of root variants can give an excellent estimate of the number of gene loci which are active in controlling root development. In tomato approximately 30% of all the mutants found after mutagenesis (disregarding flower and fruit characters) had modified root systems. One third of these had modifications of the root system only. This appears to be similar to results in peas which are still too preliminary to make an estimate. What this type of data indicates is that there is a phenomenally large number of genes involved in control of root development and that selection for desired variants should be successful utilizing existing gene pools or through mutation breeding.

The question of what to look for in a screening program appears to be the primary problem. One point which I feel needs to be made is the need for as few small roots near the soil surface as possible. These are great sites for damage and subsequent infection by disease. Their appearance late in the season may not be a disadvantage, however.