SEMINAL ROOTS OF WHEAT: MANIPULATION
OF THEIR GEOMETRY TO INCREASE THE
AVAILABILITY OF SOIL WATER AND TO
IMPROVE THE EFFICIENCY OF WATER USE

A thesis submitted
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Variation in the number of seminal roots and in the radius of the metaxylem vessel was examined in 44 wheat varieties. Subsequently two varieties were grown in a pot experiment to assess the effects of axial resistance on plant performance. A model of water uptake based on the results of the pot experiment was developed.

Development of the seminal root primordia occurred sequentially during embryo development. The slow drying of seeds, even though prematurely harvested, ensured that most root primordia were differentiated. Thus most embryos had at least five root primordia; the sixth primordium may not be formed before the development of the embryo ceases. The rate of appearance of seminal roots from excised embryos growing on agar medium increased as the concentration of sucrose in the medium was increased from 0 to 0.1 per cent. The number of seminal roots grown by seedlings decreased from 5.2 to 4.2 as mean seed weight decreased from 59 to 20 mg. Seed more than six years old had a lower number of seminal roots. The number of seminal roots was not affected by a 36 h wetting and drying cycle or by germination in soil rather than in solution. Over a temperature range of 10 to 35°C the mean number of seminal roots varied from 5.0 to 5.3, but a large variety x temperature interaction was evident.

Seedlings of 26 varieties of diverse origin were tested in solution culture for differences in the number of seminal roots and the radius of the metaxylem vessel. Differences between varieties were small: most varieties had five seminal roots. The radius of the metaxylem vessel of the primary seminal axis five centimetres from the root
base was larger with heavier seeds. The mean radius varied from 26 to 31 \( \mu m \) between varieties. A further set of 24 varieties was tested at different temperatures. The mean radius of the metaxylem vessel decreased from 35 \( \mu m \) at 10\(^\circ\)C to 30 \( \mu m \) at 27\(^\circ\)C. Varieties had a mean radius of the metaxylem vessel ranging from 27 \( \mu m \) to 36 \( \mu m \).

The pot experiment was carried out with two varieties, Warimek and Manitou, which in the initial testing had metaxylem vessel radii of 36 and 30 \( \mu m \) respectively. The pots contained 75 cm of medium clay soil as a B horizon and 45 cm of sandy loam as an A horizon. A split root techniques was used, and roots were cut to make the plants dependent on either one, three or five seminal roots from the time of stem elongation until maturity. In all pots the A horizon was allowed to dry out five weeks after planting and from then on water was available only in the B horizon. One set of pots, in which the B horizon was maintained in a wet condition, was harvested ten days after root cutting. A further two sets of pots with contrasting water regimes in the B horizon were harvested at maturity. The two water regimes were imposed after root cutting; the soil in the B horizon was maintained at field capacity in one set of the pots, while no more water was added to the other.

Plants with one seminal root lost up to 40 per cent of their leaves immediately following root cutting. Water use by the plants was directly related to the number of seminal roots per plant. Where the soil in the B horizon was maintained at field capacity, the grain yields of the plants increased as the number of seminal roots per plant increased. In contrast, plants growing in pots in which the B horizon was allowed to dry out had grain yields which decreased as the number of seminal roots per plant increased. Grain yields
were related to the amount of water used after anthesis.

Manitou tended to grow more roots after root cutting than did Wairimak. Rooting density of seminal roots increased while that of all roots, seminal plus nodal, decreased slightly with depth. The radius of the metaxylem vessels of the seminal axes of a variety was similar for different axes of the same plant and for the axes of plants harvested at stem elongation and at maturity. Although the mean radius of the metaxylem vessel of Manitou was slightly smaller than that of Wairimak (26.9 and 27.7 µm respectively) in the basal five centimetres, the opposite was true at 15 cm and below. Metaxylem vessel radius increased regularly along the axis in both varieties from a mean of 26 µm at 1 cm to 45 µm at 105 cm.

Estimates of the axial and radial components of root resistance were made with data from the pot experiment and the two resistances were included in models of water uptake. A model based on that of Gardner (1964) was used to simulate water uptake when the soil was wet. It showed that water uptake from the B horizon by all root systems was affected mostly by axial resistance, particularly in the basal 45 cm. Radial resistance differed between root systems because of differences in root length. The model also indicated that to obtain the same pattern of water uptake from the subsoil a non-tapered vessel would require a radius almost as large as the maximum radius of the observed tapered vessel in which the radius increased with depth.

For the situation where only limited water was available and the soil dried during the growing season, a model based on the equation of Lang and Gardner (1970) was developed. Initially, axial resistance
in the root was the largest resistance in the soil-root system but resistance to radial flow in the soil became dominant as the soil dried. Plants with five seminal roots used the available water more quickly than plants with one seminal root. Thus the amount of water available after anthesis was inversely related to the number of seminal roots per plant. It was concluded that when plants are dependent on water from the subsoil the grain yield will be strongly influenced by the magnitude of the axial resistance in the seminal roots.