Can deep roots remove the N-surplus?

Some of our field crops have the potential for very deep rooting, to 200 cm depth or more. In rotations, this can be used to reduce nitrate leaching.

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Most studies of agricultural N-surplus and losses have concentrated on the upper 100 cm of the soil profile. However, some of our crops can reach much larger rooting depths. Winter wheat seems to have typical rooting depths of 150 to 200 cm, and sugar beets and winter rape can have rooting depths of more than 200 cm. Experimental and model simulation studies of nitrogen dynamics have largely ignored effects below 100 cm in the soil. Potential uptake of N from below 100 cm has also been ignored in government regulation of agricultural N use.

Based on this, we have studied deep root growth of crops and catch crops and its effect on N dynamics in crop rotations.

Methods
The main methods employed in this work has been 1) the minirhizotron method for root studies, 2) soil samples and analysis of contents of ammonium-N and nitrate-N and 3) injection of $^{15}$N at various soil depths and measurement of $^{15}$N uptake in aboveground plant matter. With all of these methods we have worked to a maximum soil depth of 250 cm.

We have used these methods in a number of experiments to study differences among crops and catch crops in rooting depth and uptake of N from deep soil layers. Further, we have worked in crop sequences during 2-4 growing seasons. In these studies we have been able to investigate the effects of deep vs. shallow root growth of main crops or catch crops in a rotation on nitrogen use and on the amount of inorganic N left in the soil by the crops.

Results
Effective rooting depth of our crops vary from only 25-50 cm for some vegetable crops to 250 cm or more for others (Kristensen and Thorup-Kristensen, 2004a,b). Crucifer species show a fast development of rooting depth (Figure 1, Thorup-Kristensen, 2001; Kristensen and Thorup-Kristensen, 2004b). Among the arable crops, spring sown cereals (Figure 1) seem to reach rooting depths of around 100 cm, peas and potatoes slightly less. However, winter wheat, sugar beet and winter rape can have significantly deeper rooting, from 150-200 cm for winter wheat, more than 200 cm for sugar beet, to probably more than 250 cm for winter rape.
These rooting depths are also reflected in the ability of the crops to take N from deeper soil layers, as measured by depletion of the soil inorganic N content or by uptake of $^{15}$N injected into deep soil layers (Kristensen and Thorup-Kristensen, 2004a,b).

In conclusion, important crops can grow deep root systems and take up substantial amounts of N from soil layers below 100 cm (Figure 2). But how can deep-rooted crops be used to reduce nitrate leaching losses? One possibility is to grow more deep-rooted crops, but winter cereals, sugar beets and winter rape are already grown on almost 40% of the Danish agricultural area.

Experimental results will be shown to illustrate the two main possibilities for increasing use of deep rooting to reduce nitrogen leaching:

1) Deep-rooted catch crops: Today most catch crops grown in Denmark are grasses undersown in cereals. However, we found ryegrass to have rooting depths of only 75-100 cm (Thorup-Kristensen, 2001). Other catch crop species such as crucifers, which can be established around the time of cereal harvest, or “new” deep rooted catch crops species such as chicory (Cichorium intybus) or dyer’s woad (Isatis tinctoria) suitable for undersowing in cereals can develop much deeper root systems (Figure 1).

2) Use deep-rooted species where they are most needed: Deep roots are important where much N is available in the subsoil. This is found after leaching from the topsoil occurred. Therefore it can be valuable to grow deep-rooted crops or catch crops in the first year after a high leaching situation. Deep-rooted catch crops should be used preferably in combination with the shallow-rooted main crops in the rotation (see Thorup-Kristensen et al., 2003). As illustrated in our results, it can be advantageous to grow the deep-rooted catch crops before as well as after a shallow-rooted main crop. It can be grown before, to “lift” N to the upper soil layers where it can be reached even by a shallow-rooted main crop (Figure 2), or grown afterwards to take up the N left in the subsoil by the main crop.

Another conclusion from the work is that it is important to work to large soil depths to observe these effects at all. As most of our arable crops have effective rooting to around 100 cm, we find only limited effects of root growth within the top 100 cm of the soil (Figure 2, August). It is in the soil layers below 100 cm, where some crops have roots, but others do not, that we can observe the real differences.

**Literature**

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