The 2018 MWP Award – Full motivation

Citation

The 2018 Marcus Wallenberg Prize is awarded to Prof. Torgny Näsholm for his groundbreaking research of the role of organic nitrogen in the nutrition of trees. The ability of boreal forests to take up atmospheric carbon dioxide and produce wood for industrial uses depends on the availability of nitrogen in the soil. Prof. Näsholm's research program documented the ability of trees to use amino acid molecules as sources of nitrogen, and that these sources of organic nitrogen predominate in the nutrition of trees in boreal forests. His discoveries have substantial practical importance in sustainable management of forests, e.g., as fertilization concepts in forestry and in production of high quality seedlings in tree nurseries.

Background and Prize Motivation

Nitrogen (N, as the gas N_2) comprises 78% of the Earth's atmosphere, yet the growth of most forests is limited by a low supply of nitrogen. The N_2 in the atmosphere cannot be used by plants, although some species have developed mutualistic symbioses with bacteria that can process N_2 gas into amino acids. Soils contain very large amounts of complex organic nitrogen compounds that are released slowly over time by the activity of microorganisms. For almost two centuries, the classic description of nitrogen cycling in ecosystems (Tamm 1991) has been: a) enzymes, produced by microorganisms, break bonds in complex organic molecules, releasing small organic molecules such as amino acids; b) further microbial activity degrades the amino acids to produce ammonia (as ammonium ions); c) some of the ammonium ions are used directly by plants, and some are oxidized (nitrified) to nitrate; d) some of the nitrate is used by plants, and some is lost in leaching waters or as gases (denitrification). More than a century ago, some plants were demonstrated to have the capability of shortcutting this scheme by taking up amino acids directly (Hutchinson and Miller 1912). The direct uptake of amino acids was not considered important in the nutrition of plants until further development of isotopic methods late in the 20th Century. Prof. Näsholm's work in the 1990s and 2000s carefully explored the role of amino acids in supplying the nitrogen required for growth of forest trees (particularly Scots pine and Norway spruce); his work formed the basis for a paradigm shift in explaining N nutrition of plants (Schimel and Bennett 2004).

A first step was to demonstrate that labelled N (^{15}N) from amino acids was indeed taken up by tree seedlings (Näsholm et al. 1998). The appearance of labelled N in seedlings might have resulted from uptake of intact amino acid molecules, or it could have followed their breakdown and then simple uptake of ammonium ions. The second step for Näsholm and colleagues was in demonstrating that double-labelling of amino acids with ^{15}N and ^{13}C led to appearance of both C and N in seedlings, indicating uptake of entire amino acid molecules (Näsholm et al. 2009). The third step was demonstrating that amino acid concentrations in forests soils were high enough, relative to ammonium and nitrate, for amino acids to provide a substantial supply for tree uptake. The fourth step completed the sequence by demonstrating (through a novel micro-diffusion technique, Figure 1 and 2) that the major nitrogen source of pine and spruce in boreal forests is actually amino acids rather than ammonium ions or nitrate (Inselsbacher and Näsholm 2012).

These new insights from basic scientific research led Näsholm to develop formulations for fertilizers based on amino acid N (rather than using traditional nitrogen sources of ammonia, nitrate, or urea). Scots pine and Norway spruce seedlings supplied with inorganic N forms had greater shoot production, as typically occurs with N fertilization, but those fed organic N forms also had larger roots systems that were particularly characterized by fine roots and having more root tips colonized by beneficial mycorrhizal fungi. Field studies demonstrated improved shoot growth, as a result of a better developed root system, upon outplanting of seedlings grown on organic N. Leaching of nitrogen was also reduced compared with application of conventional inorganic fertilizer. These findings have considerable implications for nursery and forestry practices in northern coniferous forests. The first patent for this approach was issued in 2004 (US 20040025554 A1). Näsholm's work had led to the marketing of amino-acid fertilizer product (arGrow®). The fertilizer formulation is currently used mainly in forest nurseries; two of Sweden's largest nurseries currently utilize arGrow® for all of their production (approximately 40 million plants). The arGrow® fertilizers are also used in other forest tree nurseries in Sweden, Finland, USA, Canada, Uruguay, China, New Zealand and Australia. In addition, arGrow® is being tested on other commercial crops and garden plants (http://swetree.com/application-areas/argrow/)

The innovation has been further developed by Näsholm. Subsequent patents have highlighted improved plant growth using amino acids in the fertilization formula (e.g., US 7105349 B2).

Torgny Näsholm

Torgny Näsholm was born in 1959. He defended his PhD thesis in Plant Physiology in 1991 at the University of Agricultural Sciences in Umeå, Sweden. In 2000 he was appointed Professor in Plant Physiology at the Faculty of Forestry, Swedish University of Agricultural Sciences, and in 2007 he was appointed professor in Tree Ecophysiology at the same faculty.

Between 2007 and 2010 he was engaged in the company SweTree Technologies AB where his invention arGrow® was first commercialized. The arGrow technology increases plant growth, in particular the growth of roots and importantly reduces nitrogen leakage in nurseries with up to 80 %. The arGrow®-technology has been developed further into a range of slow release, amino-acid based fertilizers with unique properties. These slow release fertilizers dramatically improve growth of seedling´s fine roots which leads to enhanced rates of seedling establishment, improved survival and significantly increases growth upon plantation of tree seedlings. Further, another new technology for improved germination of pine and spruce seed in the field, called SeedPAD®, was developed within SweTree Thechnologies AB. Recently, as the leading scientist and CEO of the company Arevo AB, Näsholm further developed the SeedPAD® technology. With this technology survival rate upon plantation is increased fivefold compared to seed-sown plantation. Incorporation of the arGrow®-slow release fertilizer further enhances the performance of SeedPAD seedlings.

Torgny Näsholm has an extraordinary capability of translating and transferring his groundbreaking scientific discoveries into useful applications. During the 8-year period from 2006 to 2014 he published 34 scientific articles, of which many were in the highest ranked journals of his area of research (H-index 38 and number of citation >4000). Overall, Prof. Näsholm is the lead scientist on 11 of 14 patents issued for work on applications of amino-acid nutrition for plants.

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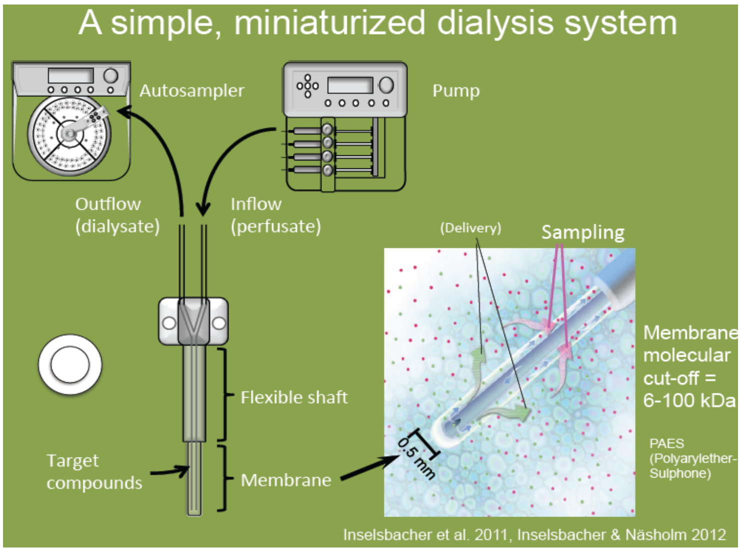

Figure 1. Torgny Näsholm's approach to examining the forms of N taken up by tree roots required development of a microdiffusion technique that replicates the microscale of tree roots and mycorrhizae (similarly to experimental approaches for examining chemistry within living animal tissues). A pump pushes very small volumes of solution through a probe placed in the soil. A semi-permeable membrane allows molecules from the soil solution to diffuse into the solution inside the probe, in which molecule concentrations are determined. The importance of simple diffusion in driving ion uptake is examined by passing distilled water through the probe. The delivery of ions by the flow of water into the probe (simulating a root) is examined by passing a fluid with low osmotic potential through the probe, leading to influx of water and ions.

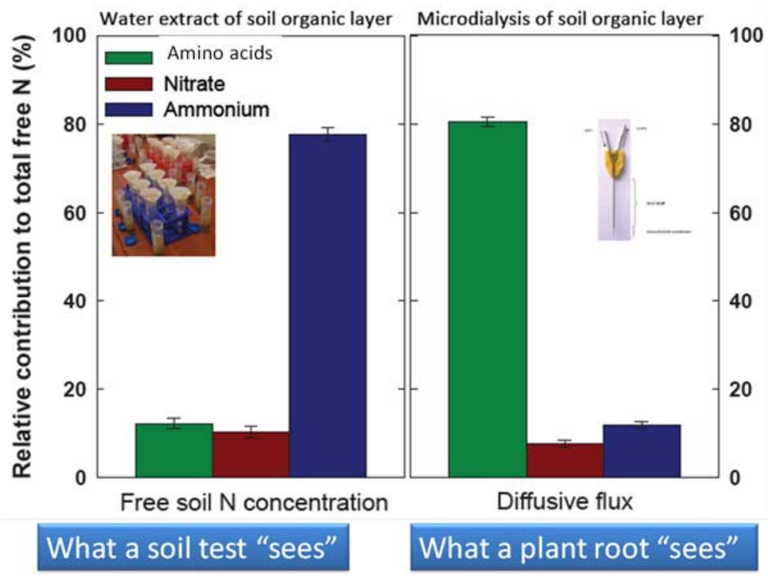

Figure 2. Across a wide range of Swedish forest soils, the concentration of available nitrogen compounds was dominated by ammonium ions (blue bar). However, the microdialysis technique showed that the greater mobility and resupply of the amino acids led to 80% of the plant-available N being comprised of amino acids, rather than the classic expectation of primarily ammonium ions and nitrate (based on Inselsbacher & Näsholm 2012).