

TURFGRASS TRENDS

NITRATE CARBOHYDRATE INTERACTION

Optimum Root Growth Hinges on Nitrogen Partitioning and Metabolism

By Richard J. Hull and John T. Bushoven

In two recent TurfGrass Trends articles (Hull & Bushoven, July 2007, page 64 and August 2007, page 56), we considered the impact that nitrate-nitrogen ($\text{NO}_3\text{-N}$) can have on the growth and function of turfgrass roots, when used as a sole (or principal) nitrogen source.

It is generally recognized that soil nitrate ($\text{NO}_3\text{-}$), after being absorbed by turfgrass roots, must first be reduced to ammonia (NH_3) before it can be assimilated into amino acids and enter the nitrogen metabolism of a grass plant. This $\text{NO}_3\text{-}$ reduction process requires a substantial amount of energy and can only occur where and when that energy is available in the form of metabolizable carbohydrates (sugars). We have shown that most cool-season turfgrasses reduce very little $\text{NO}_3\text{-N}$ to $\text{NH}_3\text{-N}$ in their roots but instead transport the $\text{NO}_3\text{-}$ to their leaves where photosynthetic energy is available to reduce $\text{NO}_3\text{-N}$ and assimilate the resulting $\text{NH}_3\text{-N}$ into amino acids. Wherever this occurs in the plant, growth normally is stimulated because amino acids, the building materials for making nucleic acids and proteins, are available. We concluded this to be one reason why abundant available $\text{NO}_3\text{-N}$ retards turfgrass root growth while stimulating leaf growth. Virtually all the evidence presented in the first two articles cited above is consistent with this idea.

If this hypothesis is true, turfgrass roots should be able to reduce $\text{NO}_3\text{-N}$ to $\text{NH}_3\text{-N}$ if they contained enough energy in the form of simple sugars. This could have practical value because root growth stimulated by $\text{NH}_3\text{-N}$ should make turf more tolerant of common stresses including heavy traffic, high temperatures and drought. What follows is our attempt to test this conclusion.

Supplying more carbohydrates to roots

The simplest way to test our idea was to grow roots in a solution containing glucose: a simple sugar easily utilized by plant cells, including root cells. Roots of perennial ryegrass (*Lolium perenne* L. cv. Palmer III) were grown in nutrient solutions contain-

Continued on page 76

IN THIS ISSUE

- **Greenhouse Technology**
A creative system allows potted turfgrass to be maintained without a lot of manpower.....80
- **Stream Maintenance**
Proper streambank planning can mitigate erosion and help prevent pollution.....84

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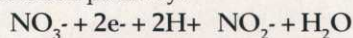
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Continued from page 75

ing 14 parts per million (ppm) $\text{NO}_3\text{-N}$ with or without glucose.

The ability of roots to reduce $\text{NO}_3\text{-N}$ was measured by assaying for nitrite ($\text{NO}_2\text{-}$), the product of the first reaction in the $\text{NO}_3\text{-}$ reduction pathway:



When glucose was included in the root culture solution, the rate of $\text{NO}_3\text{-}$ reduction was more than doubled. This confirmed our theory that $\text{NO}_3\text{-}$ reduction in grass roots was at least partly limited by insufficient energy. We tested this further by growing turfgrass cultures in a confined atmosphere containing twice the normal amount of carbon dioxide (CO_2). Doubling the CO_2 level increases photosynthesis rates twofold. Much of the additional sugar produced in leaves by photosynthesis is translocated to the roots where it stimulates their growth (Newton et al. 1996). We found that the roots of plants growing in elevated CO_2 metabolized (reduced) $\text{NO}_3\text{-}$ at twice the rate of plants growing in normal CO_2 . The percentage of total plant $\text{NO}_3\text{-}$ reduction that occurred in roots was three times greater in plants growing in elevated CO_2 . This strongly supports our theory that $\text{NO}_3\text{-}$ reduction in roots is normally energy limited and can be increased by providing roots with more energy in the form of photosynthetic products.

Which leads to a key question: Is greater root $\text{NO}_3\text{-}$ reduction due to additional carbon from leaves?

The above experiments did not prove that increased $\text{NO}_3\text{-}$ reduction by roots was actually caused by the roots having more available energy in the form of carbohydrates. We know $\text{NO}_3\text{-}$ metabolism is regulated by signal molecules, including $\text{NO}_3\text{-}$ itself (Kaiser and Huber 1994). High $\text{NO}_3\text{-N}$ concentrations in leaves will signal roots to absorb less $\text{NO}_3\text{-}$ from the soil and reduce less $\text{NO}_3\text{-}$ to NH_3 . One such signal is a lessening of sugar translocation from leaves to roots when $\text{NO}_3\text{-}$ has accumulated in the leaves. Under these conditions, photosynthetic energy in leaves is diverted toward the reduction

PHOTO 1



John Bushoven makes adjustments to growth chamber-mounted units for exposing leaves of turfgrass cultures to elevated CO_2 concentrations or $^{14}\text{CO}_2$.

of $\text{NO}_3\text{-}$ to NH_3 and the assimilation of NH_3 to amino acids resulting in the stimulation of leaf growth. Thus, we cannot be certain that greater carbohydrate availability in roots was the direct cause for their increased rates of $\text{NO}_3\text{-}$ reduction and metabolism.

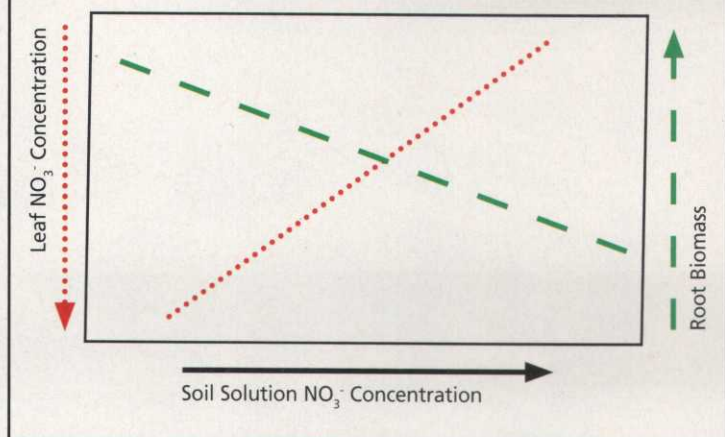
To resolve this doubt, we grew perennial ryegrass in solution cultures at high and low CO_2 concentrations. On the fourth day after initiating the CO_2 treatments, grass leaves were exposed for 30 minutes to CO_2 containing the radioactive carbon isotope: carbon-14 (^{14}C). After exposure to $^{14}\text{CO}_2$, grasses were allowed to grow for an additional 24 hours in their earlier high or low CO_2 levels after which they were harvested and assayed for ^{14}C in addition to $\text{NO}_3\text{-}$ reduction rates in leaves and roots.

We observed that the rate of $\text{NO}_3\text{-}$ reduction was

Continued on page 78

FIGURE 1

Relationship between leaf NO_3^- , root biomass and soil solution NO_3^- concentration (Generalized Relationships)



Relationship between leaf NO_3^- , root biomass and soil solution NO_3^- concentration (generalized relationships).



JOHN DEERE

QUICK TIP

Turf conditions undoubtedly vary throughout the year. For consistency, try a mower that uses adjustable hydraulic down pressure. The pressure helps keep the rear roller on the turf, yielding a consistent quality of cut without the use of springs or mechanical linkages. For information on these systems on the new line of John Deere fairway mowers, contact your local John Deere Golf distributor or visit www.johndeere.com/golf.

Continued from page 76

reduction in roots was again more than doubled by the elevated CO_2 concentration. The recovery of ^{14}C in roots was also greater in plants growing at the higher CO_2 level. In this experiment, the ^{14}C served as a tracer for photosynthetic products (sugars) produced during the 30 minutes of leaf exposure to $^{14}\text{CO}_2$. Its greater concentration in roots 24 hours later, when NO_3^- reduction rates were also greater, proves that more photosynthetic product was present when NO_3^- metabolism was stimulated and it likely contributed to that enhanced NO_3^- utilization.

Plants were also grown at high and low NO_3^- concentrations and the above observations were most evident in grass grown at low NO_3^- levels (0.5 ppm NO_3^- -N). These findings are also consistent with our observations and those of others that NO_3^- accumulation in grass leaves correlates inversely with root biomass over the long term. That is, NO_3^- in leaves diverts photosynthetic energy away from roots and toward greater shoot growth. From the perspective of sound turf management, that is not a good situation.

Conclusions

It appears that managing turf for maximum root growth is intimately related to managing nitrogen partitioning and metabolism within turfgrass plants. Any practice that slows the rate of NO_3^- absorption by roots should allow greater NO_3^- metabolism in the roots and less transport to the leaves. This relationship is governed by photosynthetic energy distribution within the grass plants. If sugars (energy) are translocated sufficiently to roots, NO_3^- will be metabolized there and root growth will be promoted.

If the turf manager understands this relationship, he/she should be able to adjust their programs to promote the allocation of plant resources from shoot growth to optimize root development. Several examples of such practices were suggested in an earlier article (Hull & Bushoven 2007b). The validity of these management strategies need to be evaluated in the field and the details likely will require refinement for each situation.

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REFERENCES

- Hull, R.J. and J.T. Bushoven. Recognizing the Nitrate Effect on Root Growth and Development. *TurfGrass Trends: Golfdom*, July 2007:64-66.
- Hull, R.J. and J.T. Bushoven. Turfgrass Root Growth, Increasing Nitrate Metabolism. *TurfGrass Trends: Golfdom*, August 2007:pages 56-58.
- Kaiser, W.M. and S.C. Huber. 1994. Posttranslational regulation of nitrate reductase in higher plants. *Plant Physiology* 106:817-821.
- Newton, P., H. Clark, C. Bell and E. Glasgow. 1996. Interaction of soil moisture and elevated CO_2 on the above-ground growth rate, root length density and gas exchange of turves from temperate pasture. *Jour. Exp. Botany*, 47:771-779.