Nitrogen nutrition in *Axonopus compressus* - nitrate and ammonium on growth and turf colour

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Introduction

Nitrogen is an important nutrient required in abundant amount to sustain vegetative growth and colour of turf. When nitrogen levels within leaf tissues fall below a critical threshold level, visible nitrogen deficiency symptoms will be expressed (**Fig. 1**). The nutrient deficiency symptoms in *Axonopus compressus* have been previously documented in RTN14-2013: Visual symptoms of nutrient deficiency in *A. compressus* (cowgrass). In summary, the nitrogen deficiency symptoms in cowgrass can be characterized as:

- **Early condition:** chlorosis (breakdown of chlorophyll) in mature leaves resulting in yellowish green leaf colour
- **Intermediate – Late condition:** Mature leaves turned reddish-purple; chlorosis in young leaves occurred
- **Late condition:** Loss of turf coverage as growth of new shoots slow or stop

Fig. 1 Nitrogen deficiency in *A. compressus* displays yellowish-green coloration with mature red leaves in contrast to (B) vigorous healthy *A. compressus* with deep green coloration

Plant nutrient uptake is mainly affected by plant needs and nutrient availability. Scheduling nutrient applications based on plant needs can promote rapid growth while minimizing the loss of applied nutrients. The form of nitrogen (nitrate, NO_3^- vs. ammonium, NH_4^+) supplied to plants affects the uptake of other cations (positively charged ions) and anions (negatively charged ions) due to their ionic charge differences. In addition, the uptake of nitrogen forms (nitrate vs. ammonium) exerts influence on rhizosphere pH (rhizosphere: narrow band of soil environment immediate to root zone). Ammonium generally causes a **decrease** in soil pH of the rhizosphere while nitrate results in an **increase** of the rhizosphere pH (Refer to **Appendix A** for further discussion on Nitrogen forms and soil pH). The increase in soil pH can lead to micro-nutrient deficiencies e.g., iron deficiency in *Axonopus compressus* commonly occurs when pH>7.0.

Axonopus compressus growth requires pH 4.5 – 7.0. It has been generally observed that plants that thrive in acid soil conditions seem to prefer ammoniacal forms of nitrogen i.e. ammonium while those adapted to higher pH soils prefer nitrate. Moreover, many plant species supplied exclusively with ammonium as their source of nutrition generally exhibit poorer growth than do nitrate-grown plants e.g. tomato plants. No previous study has been conducted to understand effects of ammonium or nitrate on growth in *A. compressus* or the preferential forms of nitrogen for growth in *A. compressus*. As such, this Research Technical Note seeks to shed light on this by documenting the effects of nitrate and ammonium on the vegetative growth and colour of this turf species. The findings from the RTN can serve to assist turf managers in selecting the preferred forms of nitrogen in their fertilizers for optimal growth and colour in cowgrass turf.

Methodology

1. The *A. compressus* plants were induced to become nitrogen deficient through weekly application of nitrogen-deficient nutrient solutions i.e. all complete nutrient elements were present except nitrogen.
2. The nitrogen-deficient plants were treated weekly with increasing levels of nitrogen at 25, 50 and 105 ppm. The nitrogen was supplied either as nitrate form (Potassium nitrate solution) or ammoniacal form (Ammonium sulphate solution).
3. Growth rate was determined by number of leaf emergence per week (**Fig. 2**).
4. Leaf chlorophyll content was estimated with a SPAD chlorophyll meter.

Findings: Nitrogen nutrition in *Axonopus compressus*

A. Growth rate

The growth rate of experimental nitrogen-deficient plants) increased with increasing nitrate or ammonium nutrient solutions (**Figs. 3 & 4**). Moreover, the growth rate was comparatively higher when the plants were fed with ammonium than nitrate. Efficacy of both forms of nitrogen treatments (at high N concentration) was rapid as turf coverage increased after one week of nutrient application (**Fig. 5**).

Fig. 2 Emergency of young leaf (*) from each vegetative shoot

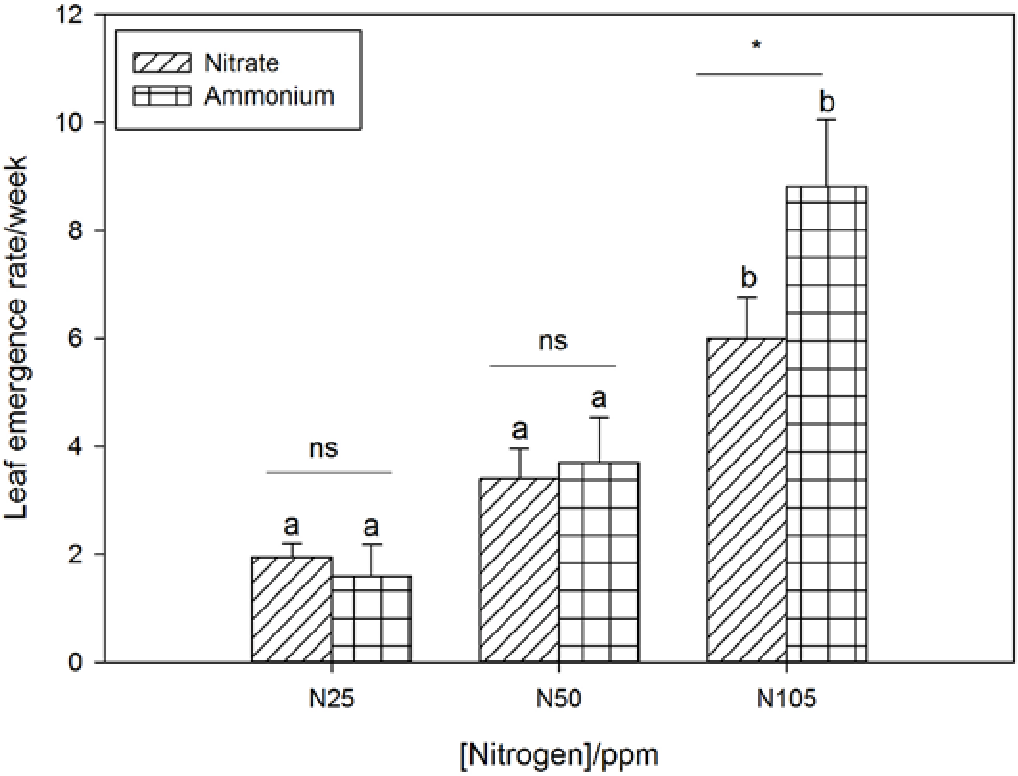

Fig. 3 Effects of nitrogen (nitrate and ammonium) concentrations (ppm) on leaf emergence rate

Means followed by the same letter between concentration treatments are not significantly different ($P<0.05$) based on Fisher's LSD test. Horizontal line indicates T-test ($P<0.05$) between Nitrogen (nitrate vs. ammonium) treatments at each concentration. *$P<0.05$, ns non-significant

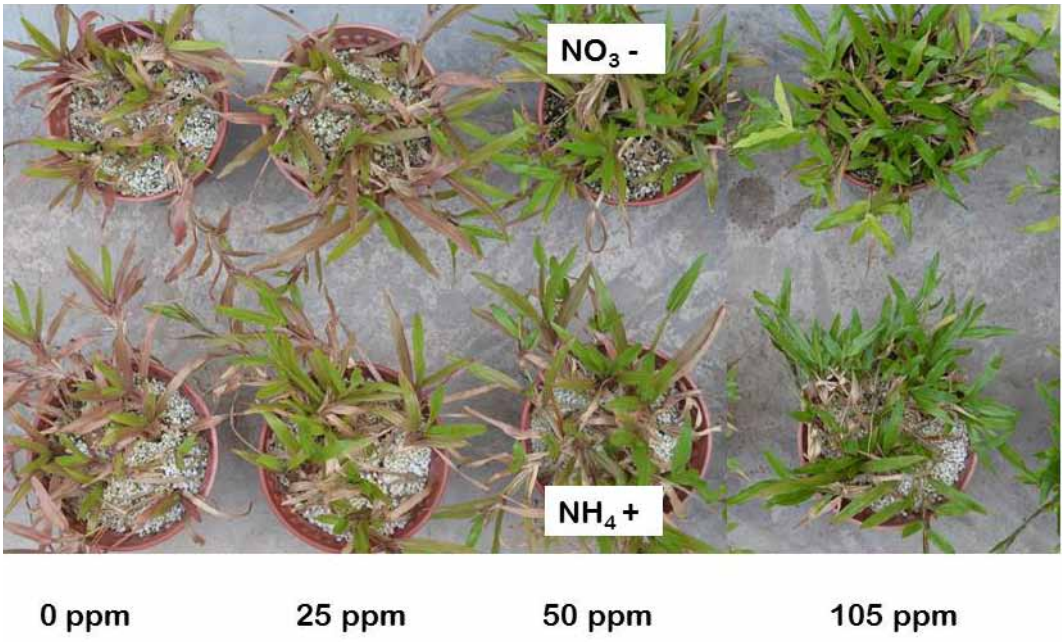

Fig. 4 Effects of increasing nitrogen concentrations (ppm), supplied as potassium nitrate or ammonium sulphate solutions, on greening and vegetative shoot production

No nitrogen, 0 ppm

Ammonium, 105 ppm

Fig. 5 Greening and turf coverage at 7 days after treatment with 105 ppm nitrogen (nitrate or ammonium). No nitrogen (0 ppm) represents control treatment

Nitrate, 105 ppm

B. Chlorophyll content

Rapid greening of the experimental nitrogen-deficient plants was observed after one week of nitrate or ammonium application (**Fig. 5**). The chlorophyll content of the nitrogen-deficient plants increased with increasing nitrogen concentration (**Figs. 5 & 6**); chlorophyll content in ammonium-fed plants was significantly higher than nitrate-fed plants at high N concentration (**Fig. 6**). The leaves of ammonium-fed plants expressed a darker green hue than nitrate-fed plants at high N concentration (**Fig. 7**).

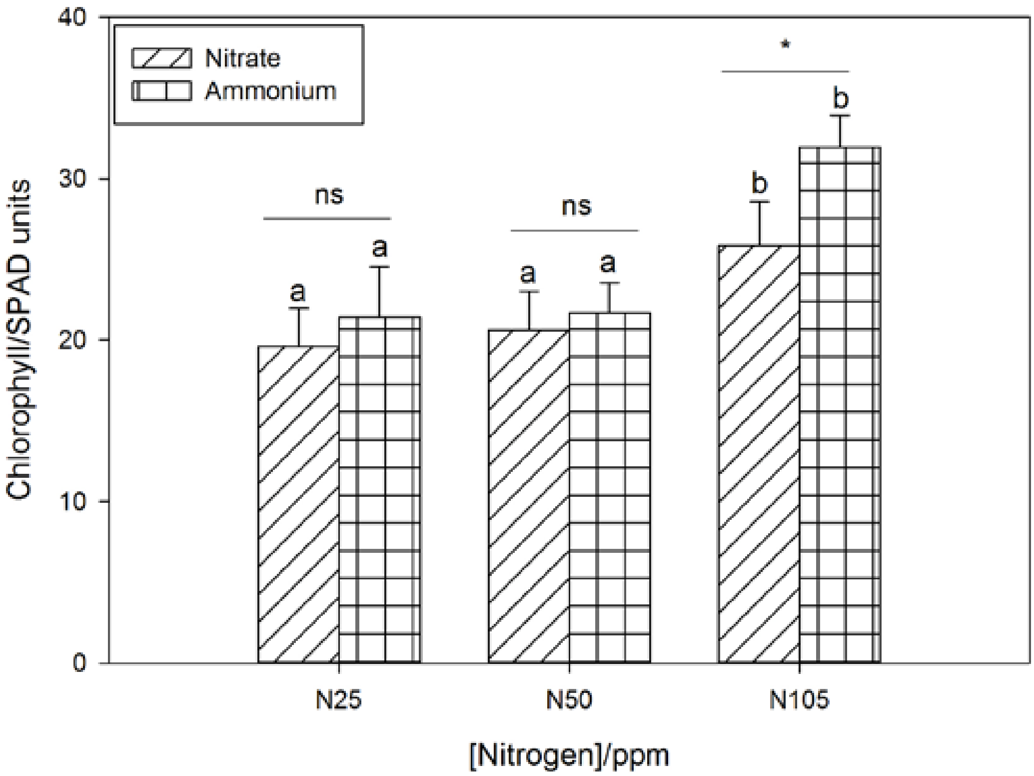

Fig. 6 Effects of Nitrogen (nitrate and ammonium) concentrations (ppm) on leaf chlorophyll content as determined by chlorophyll meter (SPAD)

Means followed by the same letter between concentration treatments are not significantly different ($P<0.05$) based on Fisher's LSD test. Horizontal line indicates T-test ($P<0.05$) between Nitrogen (nitrate vs. ammonium) treatments at each concentration. *$P<0.05$, ns non-significant

Fig. 7 Nitrate (L) and ammonium (R)-fed plants at high N concentration (105 ppm). Ammonium-fed plants appear darker green than nitrate-fed plants

Selection of fertilizer based on Nitrogen forms

There are three nitrogen forms commonly present in a synthetic fertilizer blend: ammoniacal nitrogen (NH_4-N), nitrate nitrogen (NO_3-N) and ureic nitrogen ($(NH_2)_2CO$). Commercial fertilizer blend often contain a combination of all three nitrogen forms. For example, Nitrophoska® with a 15:15:15 (NPK) composition has 30 – 50% of the nitrogen in the nitrate form and 50 – 70% in the ammonium form.

The ratio of nitrate to ammoniacal nitrogen in a fertilizer determines the rate of substrate pH change and can even be used to correct soil pH during application – nitrate fertilizer has the tendency to raise soil pH over time while ammoniacal fertilizer has the potential to lower soil pH (estimated as acidification potential), **Table 1**. High soil pH can therefore be corrected by switching to a more acidic fertilizer (high ranking acidification potential, **Table 1**) e.g., ammonium-based fertilizer such as Urea.

Table 1 Nitrogen forms and acidification potential of common fertilizers used in landscape gardening (except Calcium nitrate).

Fertilizer	Nitrogen forms	Acidification potential ranking*
Urea (46:0:0)	100% ammonium	1
Phostrogen™ (14:10:27)	2% ammonium; 12% Urea	2
20:10:10	9% nitrate; 11% ammonium	3
15:15:15	6% nitrate; 9% ammonium	4
Compost	Mainly ammonium	5
Calcium nitrate	100% nitrate	6

** The ranking is based on arbitrary acidification potential values*

Conclusion

In summary, both nitrate and ammonium nitrogen have affected the recovery of nitrogen-deficient *Axonopus compressus* in the following ways:

- Higher vegetative growth (leaf emergence rate) and chlorophyll content was observed in ammonium-fed plants than nitrate-fed plants
- The increased chlorophyll content imparts darker green hue to ammonium-fed plants
- Rapid recovery of nitrogen-deficient plants over 7 days entails high Nitrogen supply

Practical considerations: Selection of ammonium-based fertilizer promotes vegetative growth and turf colour in *A. compressus*. Furthermore, the uptake of ammonium as well as nitrification of ammonium has the added benefit of lowering soil pH. Therefore, the utility of acid fertilizers could be a favourable management practice to lower the often slightly alkaline pH of clayey soils that is commonly used in the construction of *A. compressus* lawn in Singapore.

Disclaimer: Trade names mentioned in this report are strictly for illustrative purpose and does not represent endorsement or recommendation by National Parks Board.

Appendix A

Nitrogen-forms and soil pH

Clay particles bear many negatively charged sites which enables ammonium (NH_4^+) to become readily adsorbed as they positively charged. The positive attraction reduces loss of nitrogen through leaching. Nitrate (NO_3^-) is negatively charged and is therefore not adsorbed onto clay particles and becomes free to be leached from the soil. Uptake of ammonium causes the soil pH to decrease because H^+ (acidic protons) are transported out from roots to balance the loss of positive charges outside the roots. Urea is converted into ammonium before uptake by roots. Therefore, urea can be considered as another source of ammoniacal nitrogen. However, urea has a lower acidification potential than ammonium as one H^+ is consumed during the conversion to ammonium. Nitrification is a biological reaction where ammonium is converted to nitrate by soil bacteria. During this process, two H^+ are produced causing the substrate pH to decrease. Therefore, nitrification is a significant process in reducing fertilizer use efficiency and nitrogen nutrition in plants as the relatively immobile ammonium form is converted to the mobile nitrate form. Nitrification is an aerobic reaction (non-waterlogged soil condition) that occurs rapidly under high soil temperature and neutral soil pH; this process could possibly be prevalent in some tropical soil profiles. The extent of acidification depends on whether the nitrate produced from ammonium is leached or taken up by plants. If nitrate is taken up, the net acidification per molecule of ammonium is reduced due to the consumption of one H^+ ion when nitrate is taken up. Nitrate-based fertilizers have no acidification potential and can actually cause an increase in soil pH as one H^+ is consumed in the uptake of nitrate.

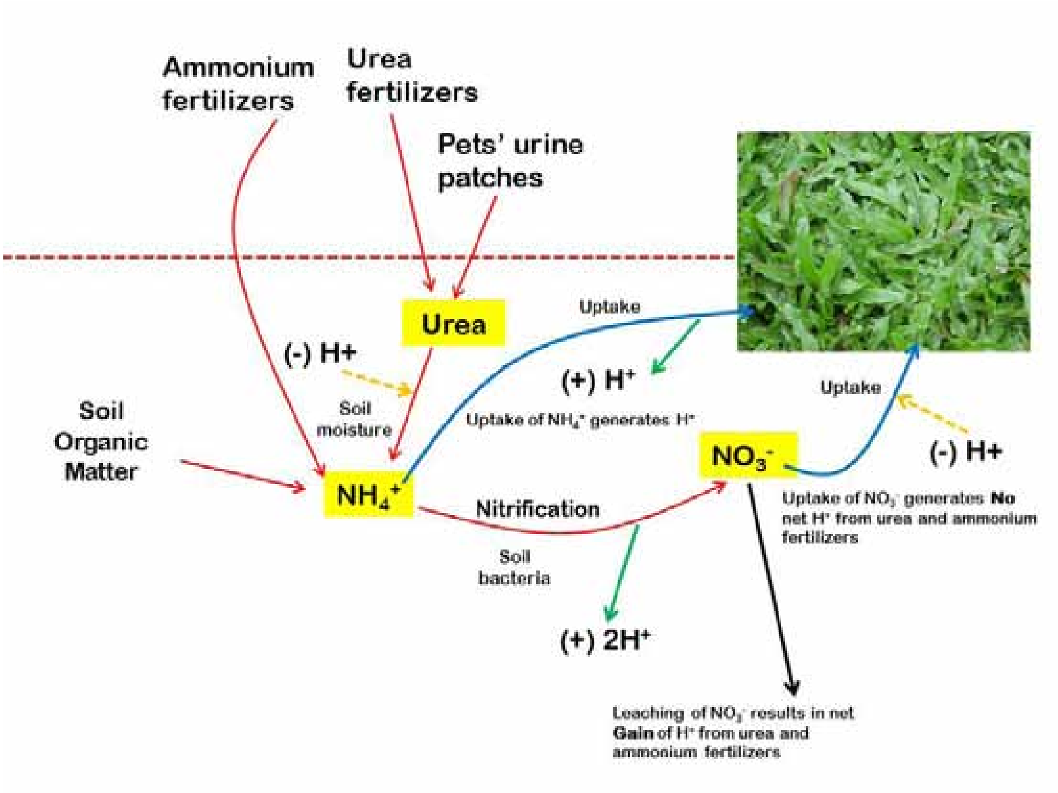

Fig. 8 Fates of nitrogen and development of soil acidity

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