Potential Losses of Nitrogen Following Fertilization of Interior Forests

Urea (46-0-0) is the preferred nitrogen (N) source for large-scale aerial fertilizer operations due to its relatively low unit price and high N content. In Interior forests, urea is often combined with ammonium sulphate (AS; 21-0-0) to provide available sources of N and sulphur (S) to fertilized stands.

The conversion of urea to available forms of nitrogen for tree uptake usually begins soon after soil application. With the enzyme urease, along with adequate soil moisture, urea is hydrolyzed to ammonia (NH_3) and carbon dioxide [$CO(NH_2)_2 + H_2O \rightarrow 2NH_3 + CO_2$]. In most cases, the NH_3 produced by hydrolysis is rapidly converted to ionized ammonium (NH_4^+) which is available for plant uptake or immobilization in soil microbial biomass. However, gaseous losses (i.e., volatilization) of NH_3 may occur under certain conditions, thereby reducing the effectiveness of the applied urea. Also, some of the NH_4^+ from urea (and from AS in urea/AS blends) may be oxidized to nitrate (NO_3^-) which is susceptible to gaseous loss (i.e., denitrification) and leaching under certain conditions. The amount of N loss, and the specific pathway by which it occurs, is influenced by several factors.

Volatilization

Urea hydrolysis proceeds very rapidly in warm, moist soils and can result in a build-up of NH_3 and a marked rise in soil pH in close proximity to urea particles (Havlin et al. 1999; Cardwell 2004). These conditions favour volatilization of surface-applied urea. Substantial volatilization losses may occur when sufficient moisture is present in the forest floor and upper mineral soil to dissolve the urea granules, but there is insufficient moisture to allow the movement of the hydrolyzed ammonia into the soil. Urea hydrolysis is relatively slow at low soil temperatures and, as a result, ammonia forms more slowly and is less prone to volatilization losses. Ammonia volatilization is also reduced when significant precipitation occurs during, or shortly after, fertilization.

Volatilization of NH_3 increases substantially as surface soil pH rises above 7 (Havlin et al. 1999). Therefore, volatilization losses following urea fertilization are usually higher in alkaline soils than in acidic soils. Fortunately, the latter conditions are prevalent in forest floors formed under Interior coniferous forests (J. Boateng, Ministry of Forests and Range, personal comm.). Ammonium sulphate is not susceptible to ammonia volatilization in acidic forest soils (Havlin et al. 1999).

Nitrogen volatilization losses from urea will be minimized where urea fertilizer is applied to acidic forest soils in either cool or dry states and when significant precipitation (> 2-5 mm) occurs within the first three to six days following fertilization. Therefore, large-scale Interior fertilizer operations should normally be scheduled for the fall, when cooler and wetter weather patterns are expected. Low volatilization losses have been reported following urea application to snow-covered ground (Preston et al. 1990). However, this practice has not yet been rigorously tested.

Leaching and Denitrification

Under certain conditions, NH_4^+ is transformed to NO_3^- through a biological process called nitrification. Whereas NH_4^+ is readily immobilized by soil microbes and absorbed on negatively charged soil particles, NO_3^- is a highly mobile anion that may be leached out of the upper soil horizons under conditions of excessive precipitation and (or) high N application rates (Havlin et al. 1999). Nitrification is also a potential gateway to N losses through denitrification, whereby NO_3^- can be biologically reduced to nitrous oxide (NO and N_2O) or dinitrogen (N_2) under saturated soil conditions. Some denitrification can also occur in well-aerated soils through accumulation of high levels of unstable NO_2^- during the nitrification process. However, this is rarely an important N loss pathway in acidic forest soils (Keeney 1980).

The amount of nitrification is affected by factors such as (1) supply of ammonium, (2) population of nitrifying organisms, (3) soil pH, and (4) soil temperature. Small populations of nitrifying bacteria, acidity of the forest floor and upper mineral soil, and relatively low temperatures generally limit NO_3^- formation in N-poor forest soils (Keeney 1980). Fertilization with urea or urea/AS temporarily raises NH_4^+ availability and will likely result in some nitrification (Keeney 1980). However, a buildup of nitrifying microbial soil populations and a high level of nitrification is unlikely to occur unless fertilizer is applied repeatedly (Havlin et al. 1999). Saturation of soil with water during spring snowmelt is likely the major potential cause of denitrification in Interior forests. However, the production of NO_3^- requires good soil aeration, and biological denitrification occurs only under anaerobic conditions (Havlin et al. 1999). Also, very little nitrification ($NH_4^+ \rightarrow NO_3^-$) is likely to occur between the time of urea or urea/AS fertilization in the fall and snowmelt the following spring.

Summary

Some gaseous and leaching losses of N can be expected following urea or urea/AS fertilization of Interior forests. However, the nature of Interior forest soils (low pH and temperature and small populations of nitrifying bacteria), and the conditions under which fertilizer is applied (cool weather with a high probability of significant precipitation during, or shortly after, fertilization) will usually ensure that a relatively small amount of the added N is lost following operational fertilization. The relatively dry continental climate and a single application of a moderate amount of N will also help minimize N losses in fertilized Interior forests.

References

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