Estimated NH₃-volatilization losses from surface-applied urea on a wet calcareous Vertisol

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Abstract. Severe losses of NH₃ by volatilization are often reported when urea is surface applied to calcareous soils. Applications on wet soils may increase these losses. This study with N rates of 0, 20, 40, 80, 160, and 320 kg ha⁻¹ estimates the efficiency of urea application and predicts NH₃-volatilization losses when urea is surface applied on a wet calcareous soil. Placements consisted of three different methods of applying urea on or in the dry soil just prior to irrigation and a surface-broadcast treatment following irrigation.

There were no significant yield differences between dry-soil placements, but all dry-soil placements gave significantly higher yields than did broadcast placement of urea on the wet soil. Thus, a second-order regression equation relating N rate and yield for dry-soil placements and another for wet-soil placement were used to determine the efficiency of wet- vs dry-soil applications of urea and to predict NH₃-volatilization losses from the wet soil. The efficiency was determined by three different procedures. The first compared the amount of N needed for wet- vs dry-soil conditions to produce discrete yields. The second compared the slope of the yield curves at discrete yield levels to determine the ratio of the amount of N needed to produce one additional increment of yield under wet- vs dry-soil conditions. The third was an estimation of the availability coefficient according to a method recently developed by HR Tejeda and others. Predicted NH₃-volatilization losses were calculated from the efficiency values because loss of NH₃ from urea applied on or in dry soil followed very shortly by an irrigation should be almost nil.

The efficiency factors averaged 55% for the first procedure and 51% for the second while the availability coefficient was 59%. Thus, the average estimate for efficiency of urea on wet vs dry soil was 55% and predicted losses of N by NH₃ volatilization averaged 45% when urea was applied to the wet surface of this calcareous soil.

Many studies conducted in the laboratory, greenhouse, and field have shown that moderate to very serious losses of N by volatilization of NH₃ can occur when urea is placed on the surface of calcareous soils [1, 2, 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23, 24, 25, 27, 31] or those with free CaCO₃ from a recent liming [6, 19, 28, 32, 33]. In fact, these N losses reached an extreme of 70% [12, 23] and exceeded 50% in 7 other studies while the maximum reported losses averaged 34%.

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These N losses from NH₃ volatilization on calcareous soils may be greater when urea is surface applied to wet soils than when it is applied on dry soils. With surface applications of urea, Nommik [22] recovered only 35% of the N on wet soil, and 81% on dry soil. By using similar applications Acquaye and Cunningham [1] found slight loss of N on dry soil, greater losses with increased moisture, maximum losses at about 25% of the water-holding capacity (WHC) and gradually decreased losses at higher moisture contents. Fenn and Escarzaga [7], however, found no significant difference in NH₃ loss from urea applied on wet or dry surfaces.

Other studies that investigated losses of NH₃ from surface-applied urea on soils with mid-range moisture contents report somewhat varied findings. The NH₃ loss data show a slight fluctuation from 40% to 60% WHC [9], no difference at 25, 75 and 100% moisture capacity [15], a decrease with increased soil moisture from 50% to 75% WHC [20], a considerable decrease with increased soil moisture from 25% to 80% WHC [24] and a sharp decrease when soil moisture was increased from 25% to 75% of the standard irrigation [21].

Because of differences in soil characteristics (moisture, pH level, CaCO₃ content, texture, cation exchange capacity, salinity, organic matter content, etc), relative humidities, temperatures, rates of urea application, wind velocities, wetting and drying cycles, time, etc, which are beyond the scope of this paper; the results of these studies may appear contradictory. However, a pattern develops if one first observes the effect on dry vs wet calcareous soils. Because free water is needed before urea is converted into (NH₄)₂CO₃ in the presence of urease, urea applied to the surface of a very dry soil under very low ambient humidity will not lose much NH₃ by volatilization. However, if sufficient moisture is present to allow complete conversion and the ammonium compounds formed remain at or near the surface, considerable losses of NH₃ can be expected, primarily because of the decomposition of (NH₄)₂CO₃ [2, 8, 27].

Between these two extremes, as the moisture content of the dry soil is increased, more urea is converted to (NH₄)₂CO₃. This compound, other ammonium salts, and any unhydrolysed urea may remain at or near the surface until sufficient moisture is present to allow movement to lower depths. Therefore, NH₃ volatilization increases until a certain moisture content, which is dependent upon soil characteristics and ambient conditions, is reached. Then these losses decrease at higher soil moisture contents perhaps until a state of flooding [30] and anaerobic conditions occur. Chin and Kroontje [4], who found less volatilization of NH₃ from (NH₄)₂CO₃ applied to wet soils, attributed it to increased water surface area for NH₃ absorption. This factor helps explain the decreased volatilization losses in wetter soils. Although the level of soil moisture between a dry and a wet soil at which the NH₃ volatilization stops increasing and starts decreasing varies from soil to soil, the data reported in the literature cited indicate that a value close to 25% WHC should approximate this point.