for the differences in total volatilization losses since organic matter content and CEC were higher at Naranjal in comparison with the soil at Paraguaicito. However, the differences in soil pH and texture between the soils of both sites were likely not significant enough to explain the differences in the observed NH_3 volatilization.

It has been documented in coffee plantations in Colombia that air temperature in the top 2 m over the ground is highly correlated with temperature in the first 10 cm of the soil profile (Jaramillo, 2005). This condition is in turn influenced by other climate factors such as solar radiation, wind velocity, water evaporation, rainfall, and soil factors including tillage, organic matter content, and soil moisture. **Figure 4** shows the average temperature registered over the 20 days of evaluation at both sites. The data suggest that the lower average temperature at Naranjal during the evaluation period was associated with lower N volatilization losses. Volatilization losses are greater as temperature increases due to the increment in microbial activity, particularly microorganisms that produce the urease enzyme (Hargrove, 1988).

Figure 4 also shows daily precipitation through the evaluation period at both sites. At Naranjal, total accumulated precipitation during the 20 days of evaluation was 252 mm, while at Paraguaicito it was only 128 mm. The lower N volatilization at Naranjal can be related to the higher amount of rainfall during the first five days of evaluation, or the period when the highest amount of N losses occurred at both sites. Higher soil moisture due to more rainfall reduces N volatilization losses because it dilutes the concentration of OH^- ions that builds around the urea granule during urea hydrolysis and helps to incorporate NH_4^+ into the soil profile (Lara et al., 1997).

The combined plant density and age condition of the plantation could explain the fact that 40 mm of precipitation on day 2 at Naranjal did not move the urea far enough into the soil to shut down volatilization losses. Around 50% of the total amount of water which falls in a precipitation event is retained in the coffee plant canopy and in the thick mulch layer accumulated on the soil as a result of normal leaf loss and trimming (Jaramillo, 2003; Velásquez y Jaramillo, 2009). Consequently, only around 50% of the rainwater reached the soil to upset urea reactions at that point in time.

Conclusions

Data from this study demonstrate that NH_3 volatilization losses from urea applied to the soil surface in established coffee plantations are significant and occur over a short period of time. The combined effect of soil and climate influence the total N loss, but in any situation it is necessary to adjust fertilizer management practices to minimize these losses. BC

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