



Nitrate Leaching Pulses After First Monsoon Rains in Fertilised Maize Plots

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Abstract

In monsoon climates the opening rains of the season fall on soil that has been dry for months, and in maize systems they usually arrive within days of sowing and basal fertiliser application. This communication draws attention to the short period that follows, in which three things coincide: a store of nitrate carried over from the dry season, a burst of nitrogen mineralisation triggered by rewetting, and fertiliser nitrogen newly placed in the soil. The young crop can take up very little of this supply, and the first drainage events can carry a disproportionate share of the season's nitrate loss below the root zone. The note summarises the soil processes behind the pulse, drawing on the long-established literature on drying and rewetting and on nitrate leaching, and explains why fertilised maize is particularly exposed. It then comments on how the pulse can be observed, since its brevity and its dependence on preferential flow make it easy to miss with routine sampling. No new measurements are reported. The purpose is to argue that leaching studies and nitrogen recommendations in monsoon maize should treat the onset of the rains as a distinct period with its own sampling and management requirements.

Keywords: Nitrate leaching, Monsoon onset, Maize, Drying and rewetting, Nitrogen mineralisation, Fertiliser timing

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1. Introduction

Nitrate is the form in which most nitrogen is lost from cropped soil to groundwater. It is highly soluble, it is repelled by the negatively charged surfaces that dominate most soils, and it moves wherever water moves (Addiscott et al., 1991). Loss by leaching is therefore governed by two conditions that must hold at once: nitrate present in the profile, and water draining through it (Di and Cameron, 2002). The health significance of the loss is reflected in the guideline value of 50 mg/L for nitrate in drinking water set by the World Health Organization (WHO, 2017), which shallow wells beneath intensively farmed land can exceed.

In temperate agriculture the two conditions coincide mainly in autumn and winter, and much of the

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classic research concerns that season. In monsoon and other seasonally dry climates the calendar is different. The risk is concentrated at the start of the rains, when the soil holds the most nitrate it will hold all year and the crop is least able to use it. This short communication sets out the reasoning, with fertilised maize as the case in point, and comments on what it implies for field studies and for advice to growers.

2. Why the First Rains Release Nitrogen

The flush of mineral nitrogen that follows the wetting of dry soil is among the oldest observations in tropical soil science. [Birch \(1958\)](#) showed that drying followed by rewetting stimulates the decomposition of soil organic matter and the release of mineral nitrogen, and that the effect grows with the length and severity of the preceding dry period. Field measurements in East Africa documented the same seasonal flush across arable soils and climates ([Semb and Robinson, 1969](#)). Later work attributes the effect to two sources of substrate: microbial cells killed by desiccation or ruptured by sudden rewetting, and organic matter exposed when aggregates slake ([Fierer and Schimel, 2002](#); [Borken and Matzner, 2009](#)).

The flush adds to nitrate that is already there. Mineralisation and nitrification continue slowly into the dry season after the previous harvest, with no crop to take up the product and no drainage to remove it, and evaporation draws some nitrate toward the surface. The first rains therefore meet a topsoil that is enriched before the microbial response begins.

3. Why Fertilised Maize Is Exposed

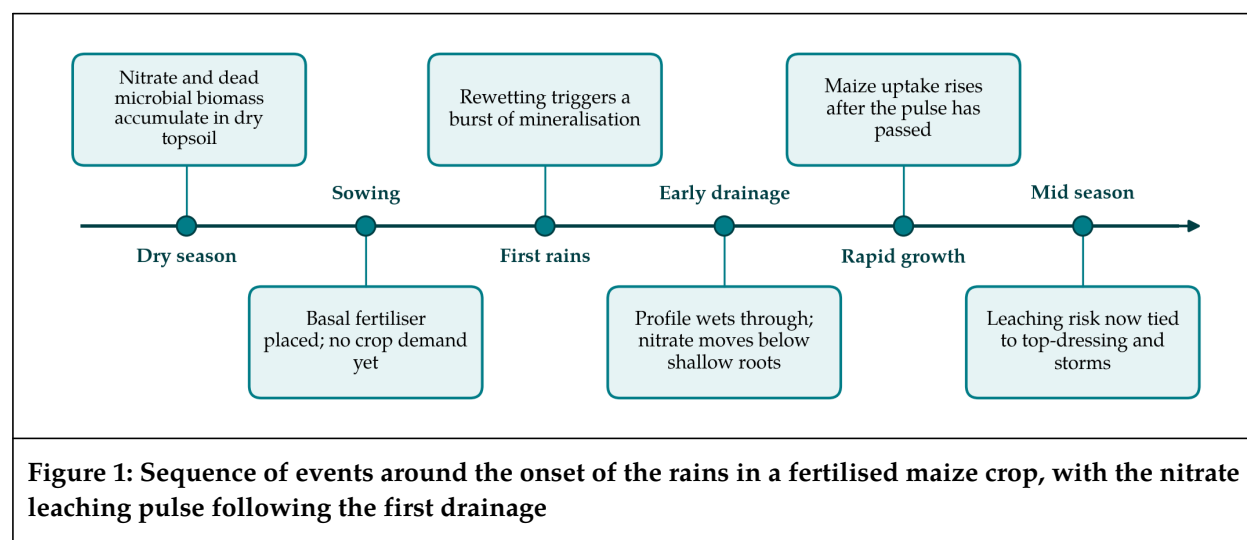
Maize is sown at or just before the onset of the rains so that the crop can use the full season, and a basal dressing of nitrogen fertiliser is commonly applied at sowing. The crop's demand for nitrogen in the first weeks after emergence is small. Uptake accelerates only as the canopy closes and the stem elongates. Efficient nitrogen management depends on matching supply to that demand in time ([Cassman et al., 2002](#)), and at the onset of the rains the match is at its worst. Table 1 lists the factors that combine during this period and the response each suggests.

Table 1: Factors that combine to produce a nitrate leaching pulse at the onset of the rains, and the management response each suggests		
Factor	How it contributes	Management response
Carry-over nitrate	Residual nitrate accumulates in topsoil through the dry season	Test soil before sowing; credit it in the recommendation
Rewetting flush	Rapid mineralisation in the first days after rain	Allow for it when setting the basal rate
Basal fertiliser	Soluble nitrogen applied before the crop can use it	Reduce the basal share; split the remainder
Low early uptake	Small root system and low demand for several weeks	Place fertiliser near the row
Intense early storms	Drainage begins once the profile wets through	Keep residue or cover to slow infiltration fronts
Coarse or cracked soil	Fast or preferential flow past the matrix	Give most weight to splitting on these soils

Soil type modifies the outcome. Sandy soils wet through quickly and hold little water, so that drainage, and nitrate with it, begins after relatively little rain; mineral nitrogen dynamics and leaching of this kind have been described for maize on a sandy loam in Zimbabwe ([Chikowo et al., 2004](#)). In cracking clays the first storms may run down shrinkage cracks before the soil swells. Some strongly weathered subsoils carry positive charge and retard nitrate, which delays the loss without preventing it ([Cameron et al., 2013](#)).

4. Observing the Pulse

A pulse that lasts days is poorly captured by sampling designed for seasonal totals. Soil cores taken monthly can miss it altogether, and they cannot separate nitrate leached from nitrate immobilised or denitrified. Suction cups sample the soil solution at a point and may be bypassed by water moving in macropores, while lysimeters collect drainage directly but are costly and disturb the soil; the strengths and weaknesses of each are reviewed by [Weihermüller et al. \(2007\)](#). Figure 1 places the pulse in the sequence of events from the dry season to mid-season, which indicates when sampling effort should be concentrated.



Three practical points follow for study design. Instruments should be installed and settled before the dry season ends, since installation after the first rain is already too late. Sampling should be triggered by rainfall events and not by the calendar, with frequent collection through the first drainage events. And mineral nitrogen in the profile should be measured immediately before the rains, because without that baseline the fertiliser contribution cannot be distinguished from the carry-over and the flush. An unfertilised reference plot serves the same purpose.

5. Implications for Nitrogen Management

If a substantial share of the season's leaching risk falls before the crop enters rapid growth, the most direct response is to have less soluble nitrogen in the soil at that time. Splitting the application, with a modest basal dose and the bulk applied when uptake is accelerating, is standard advice for this reason ([Cameron et al., 2013](#)). The reasoning here adds that the size of the basal dose should take account of the nitrogen the soil itself supplies at the onset of the rains, which in soils with a long dry season and reasonable organic matter may meet much of the seedling's early requirement. A pre-season soil nitrate test, where laboratories are accessible, puts a number on that supply.

These suggestions are inferences from established process knowledge. Their size and their reliability will differ between soils and rainfall regimes, and they need to be checked by event-based measurement in the systems concerned before they are written into recommendations.

6. Conclusion

The onset of the monsoon brings together stored nitrate, a mineralisation flush, freshly applied fertiliser and a crop too small to use them, at the moment drainage resumes. The resulting leaching pulse is brief, and routine sampling tends to overlook it. Treating the first rains as a distinct period, in the design of leaching studies and in the timing of nitrogen for maize, would direct attention to where the loss is most likely to occur.

Conflict of interest

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