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Minimizing Nutrient Leaching from Maize Production Systems in India with One-Time Application of Multi-Nutrient Fertilizer Briquettes

Sunil B.H.[1*], Lal Chand Malav[2], Brijesh Yadav[2] and Ankhila R.H.[3]

[1]ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur, Maharashtra (440 033), India
[2]ICAR-National Bureau of Soil Survey and Land Use Planning, RC, Udaipur, Rajasthan (313 001), India
[3]ICAR-Indian Institute of Water Management, Bhubaneswar, Odisha (462 038), India

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Corresponding Author
Sunil B.H.
e-mail: sunilbh62@gmail.com

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Abstract

Nutrient losses through surface runoff and leaching from agricultural lands could have negative effects on surface water and groundwater resources in India. Nutrient management strategies that synchronize nutrient uptake with availability will increase nutrient recovery efficiency and minimize nutrient losses to the environment. Concentrations of leachate N from the two briquette treatments were consistently similar to background levels throughout the sampling periods, with the farmer practice resulting in the greatest leachate N concentrations, followed by its modifications. There were no significant treatment effects on leachate P and K concentrations. Therefore, for environmental sustainability, the one-time application of multi-nutrient fertilizer briquettes could be an ideal fertilizer management strategy for maize production. In addition to the environmental benefit of decreased nutrient leaching, one-time application of multi-nutrient fertilizer briquettes could provide significant agronomic benefits of increased yields from increased nutrient retention in the soil and improved nutrient utilization by the maize plants.

Introduction

Maize (*Zea mays* L.), one of the most prominent cereal crops cultivated in India, requires large amounts of organic and inorganic fertilizers to achieve high yields. For most crops, including maize, nutrient uptake is largest several weeks after planting, creating a time gap between pre plant fertilizer application and significant plant N uptake. Thus, it is virtually impossible to produce maize other agricultural products without nutrient losses to ground and surface waters, and/or gaseous emissions to the atmosphere. This introduces a problem for possible nutrient contamination in drinking water and represents nutrients losses for the plant. A major challenge facing agriculture in recent times is to minimize nutrients in soil reaching ground and surface waters while at least maintaining if not increasing crop productivity (Delin and Stenberg, 2014).

Synchronizing nutrient fertilization with plant nutrient demand has been proposed as a best management practice to reduce nutrient leaching losses. One way to accomplish this is by applying fertilizer several weeks after corn has emerged (side-dress stage). However, application at planting is preferred by farmers due to the short window of time that is often available for field operations before plant N requirements are high, and as pre plant application is less costly to apply. Therefore, developing fertilizer products that allows for application at planting, with minimal nutrient losses is of importance for agronomic and environmental sustainability. Currently, nutrient management strategies utilized worldwide to improve nutrient recovery efficiency include the use of slow and controlled release fertilizer types, splitting N recommendations into several applications, and precision agriculture. Nitrification and urease inhibitors added to urea-based fertilizers potentially offer better synchronizing nutrient release with plant requirement. Urease inhibitors (UI) slow the rate at which urea is hydrolyzed to ammonium (NH_4^+) (Timilsena *et al.,* 2015). By doing so, UI delay release of N until soil conditions are less likely to cause loss, which may also reduce losses *via* nitrate (NO_3^-) leaching. Nitrification inhibitors (NI) slow the microbial conversion of NH_4^+ to NO_3^-. Hindering the nitrification rate with a NI, NO_3^- leaching is reduced by maintaining N in the less mobile NH_4^+ form. Coating urea with polymers and other materials such as neem (*Azadirachta indica* L.) oil, biochar, elemental sulfur, and phosphogypsum (Vashishtha *et al.*, 2010) have all proved effective in reducing N leaching losses. Although all the N management strategies are effective in improving N use efficiency and thereby reducing leaching losses associated with application of granular/ prilled urea, the cost associated with these practices make them unrealistic nutrient management strategies for resource-poor smallholder farmers.

One practical and cost-effective nutrient management strategy smallholder farmers in India could adapt to reduce nutrient leaching losses and improve fertilizer efficiency is the fertilizer deep placement (FDP) technology. The FDP is a farmer-friendly technology that utilizes briquetted fertilizer sources, and allows for one-time application at planting, which can minimize nutrient leaching losses, without affecting maize yield. The technology involves two elements: (i) applying physical pressure to compact granular fertilizer grades into a large-sized fertilizer particles of 1-4 grams by weight, referred to assuper granules or briquettes, and (ii) point placement of the briquettes ~ 10 cm away from the plants and at 7-10 cm depth near the root zone of the crop being fertilized. Through the FDP technology, the avenues for nutrient losses are reduced, thereby improving nutrient uptake efficiency. Use of multi-nutrient fertilizer briquettes resulted nutrient use efficiency of > 66% compared to 35% from treatments with granular/ prilled fertilizer sources and applied fertilizer briquettes to rice produced under tidal flood conditions and observed substantial increases in fertilizer recovery, and use efficiencies relative to the traditional farmer practice of applying granular fertilizer.

Few studies have examined the effectiveness of the multi-nutrient fertilizer briquettes on upland crop production, particularly in maize. Agyin-Birikorang *et al.* (2018) showed that the effectiveness of the multi-nutrient fertilizer briquettes is highly dependent on weather variables, particularly soil moisture, with effectiveness being reduced under dry conditions.

Due to the reduced surface of the fertilizer briquettes that result in reduced dissolution rates, and subsequently synchronizing nutrient release with uptake. We hypothesized that one-time application of the multi-nutrient fertilizer briquettes will minimize nutrient leaching losses compared with a conventional granular/ prilled fertilizer products, without sacrificing crop yields and other agronomic benefits.

Production of the Multi-Nutrient Fertilizer Briquettes

The local agricultural extension fertilizer recommendation for maize is 250 kg ha^{-1} of NPK compound fertilizer (usually 15:15:15 or 17:17:17). This is usually applied basally at planting or shortly after seedling emergence, and an additional 125 kg ha^{-1} of urea is applied as a side-dressing 6 weeks after planting. This makes the actual nutrient recommendation per hectare: 100 kg N, 42.5 kg P_2O_5, and 42.5 kg K_2O. Based on this recommendation, a combination of 250 kg of NPK compound fertilizer and 125 kg of urea were thoroughly mixed for the briquetting. Pre-determined quantities of the granular fertilizer products were crushed and fed into a briquetter that is equipped with two rollers that, by pressure alone, forms the materials into briquettes of uniform size. The briquettes utilized for the experiments were produced in two sizes, a 3-gram size and a 2.25 gram size, with each briquette having a final nutrient composition as follows: 26.7% N, 11.3% P_2O_5, and 11.3% K_2O.

Effects of Fertilizer Treatments on Nutrient Leaching

The measured N concentrations varied over the sampling period, showing "peaks and valleys" in both years. This could be attributed to the rainfall intensity that occurred prior to soil water sampling. Generally, more rainfall immediately before sampling results in a lower leachate N concentration measurement, which could result from a dilution of the leached N. Unfortunately, the actual volume of water that percolated through the soil at each rainfall event could not be measured, and empirical calculations based on basic meteorological data introduced numerous unjustified assumptions so that the actual mass of leached N could not be quantified. Across the three locations and in both years, the leachate N concentrations of the two briquette treatments were consistently similar to the control plots throughout the sampling periods; however, the leachate N concentrations of the two briquette treatments were significantly less than the treatments that received granular fertilizer application (farmer practice and its modification treatments). On the other hand, the highest leachate N concentrations were consistently measured from the farmer practice treatments, confirming that a large portion of the applied N that should have accumulated in the soil as residual N was lost in leaching. Approximately 1.5 to 2 weeks after basal fertilizer application, high N concentrations of ~ 6-8 mg L^{-1} were measured from the farmer practice treatment, followed by the 100% modified farmer practice and the 75% farmer practice treatments.

The N concentration values from these treatments began to decrease thereafter, until about the 7th week after the split application of urea when the leachate N concentrations began to increase. N leaching reached its peak between the 8th to 9th weeks. As previously observed during these periods, the leachate N concentrations were greatest in the farmer practice treatment, followed by the 100% modified farmer practice and the 75% modified farmer practice treatments, in that order. After the 9th week of basal fertilizer application (approximately 3 weeks of split urea application), the leachate N concentration began to decrease, until it reached the background levels at approximately the 11th week of basal fertilizer application. However, the briquette treatments maintained near constant leachate N concentrations that were comparable to the background (leachate N concentrations from the control treatment) levels (Kapoor *et al.,* 2008).

Conclusion

The farmer practice resulted in the greatest leachate N concentrations, followed by its modifications. There were no significant treatment effects on leachate P and K concentrations. Thus, apart from increasing maize yields and ensuring efficient utilization of applied fertilizers, one-time application of the multi-nutrient fertilizer briquettes ensures a tremendous reduction of N leaching associated with the current farmer practice of surface broadcasting granular fertilizer. From the combined results, we conclude that, for environmental sustainability, adoption of the one-time application of the multi-nutrient fertilizer briquette could be an ideal fertilizer management strategy for maize production.

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