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Research Application Summary

Effect of controlled release urea on soil nitrogen mineralization and maize yield in Siaya County, Kenya

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Abstract

Although nitrogen (N) is a major limiting nutrient in most soils in Kenya, it is often lost before it is used up by crops. This is due to the high dynamics of its transformations in the soil, making it easily lost from the soil. This usually leads to reduction in crop yield and environmental pollution through contamination of underground water resources. Appropriate management of soil fertility is key in realizing increased food productivity in Kenya with minimum environmental pollution. Controlled release urea fertilizers are one such strategies. This study investigated the N mineralization and yield of maize when using normal urea (NU) or controlled release urea (CRU) under conservation agriculture (CA) or conventional tillage in Siaya County. The experiment was superimposed on a long term trial with tillage system as the main plot and urea type as the split plot. Results showed significantly (P=0.05) lower nitrate concentrations with CT+CRU and CA+NU in the early stages of the season. Maize yields were not influenced by the urea type but were higher in conventional tillage systems than in conservation agriculture systems. More repeat studies are however necessary before conclusions can be made on the potential for CRU to reduce soil nitrate concentrations in Kenya.

Key words: Controlled release urea, conservation agriculture, nitrogen losses, nitrogen mineralization

Résumé

Bien que l'azote (N) soit un nutriment limitant majeur dans la plupart des sols au Kenya, il est souvent perdu avant d'être utilisé par les cultures. Ceci est dû à la forte dynamique de ses transformations dans le sol, ce qui le rend facilement perdu du sol. Ceci entraîne généralement une réduction du rendement des cultures et une pollution de l'environnement par la contamination des ressources en eau souterraines. Une gestion appropriée de la fertilité des sols est essentielle pour réaliser une productivité alimentaire accrue au Kenya avec une pollution environnementale minimale. Les engrais à base d'urée à libération contrôlée font partie de ces stratégies. Cette étude a examiné la minéralisation en N et le rendement du maïs lors de l'utilisation d'urée normale (NU) ou d'urée à libération contrôlée (CRU) dans le contexte de l'agriculture de conservation (CA) ou du travail de sol conventionnel dans le Comté de Siaya. L'expérience a été superposée sur un essai à long terme avec le système de travail du sol comme parcelle principale et le type d'urée comme parcelle divisée. Les résultats ont montré des concentrations de nitrate significativement plus faibles (P = 0,05) avec CT + CRU et CA + NU au début de la saison. Les rendements du maïs n'étaient pas influencés par le type d'urée mais étaient plus élevés dans les systèmes conventionnels de travail du sol que dans les systèmes d'agriculture de conservation. Des études répétées sont cependant nécessaires avant de pouvoir tirer des conclusions sur le potentiel de CRU à réduire les concentrations de nitrate dans le sol au Kenya.

Mots clés: Urée à libération contrôlée, agriculture de conservation, pertes d'Azote, minéralisation d'Azote

Introduction

Agricultural productivity in most Kenyan soils has not improved much, and with the growing human population, it is paramount to increase food production. The low yield of major crops such as maize which is a staple crop for Kenya's majority is partly due to low soil nutrients. Soil fertility in Kenya is constrained by a number of factors one of which being continuous cropping without adequate nutrient replenishment. Like in many parts of Kenya, Nitrogen is one of the most limiting nutrients in Siaya County (Kihara and Njoroge 2013). However, N losses after fertilizer application usually occur through leaching of nitrate or volatilization of ammonium. Further N losses occur when excess nitrates in the soil is emitted as nitrous oxide through denitrification process by soil microorganisms. The environmental effects associated with nitrogen fertilizer use include underground water pollution by excess nitrate or atmospheric increases in nitrous oxide which is believed to be a dangerous greenhouse gas with a global warming potential 300 times more than carbon dioxide (Forster *et al.,* 2007). Although food production has been shown to increase with increasing N fertilizer application, the detrimental effects of excess N must also be considered in designing or adopting strategies. One such strategy would be to use controlled release urea fertilizers. These fertilizers are designed to release N slowly and when the crop demand is higher, leaving less N in the soil to be lost (Shaviv, 2001). This has also been shown to increase N use efficiency and often leading to higher grain yield. CRU has also an economic advantage in large scale farming since the application is done once and the cost of labour associated with topdressing can be reduced (Han *et al.,* 2009). The use of CRU in Kenya especially in field crop production has not been reported. The aim of this study was to test the potential of CRU in reducing concentrations of mineral N in the soil and increase maize yields. We hypothesized that CRU would release N nutrients when the maize plants demand for N was high and therefore increase grain yield over the normal urea.

Material and methods

Study site

The study was carried out in the long rainy season 2016 at International Centre for Tropical Agriculture (CIAT)'s long term maize trial in Siaya County (0 7' N and 34 24' E). The trial was set up in 2003 focusing on conservation agricultural practices. The area lies at an altitude of 1420 meters above sea level. The climate is sub-humid, with a mean annual temperature of 22.5 C and average annual rainfall of 1727 mm distributed over two rainy seasons: the long rainy season starts in March and ends in August while the short rainy season occurs between September and January (Siaya Integrated County Development Plan, 2013-2017). The soils in the area are acidic (pH between 4.9 and 5.5), low CEC and high aluminum saturation, with low organic matter content (Kihara, 2009).

Study design and layout

The experiment was laid out in a split plot design with the tillage system as the main plot and urea type as a split plot replicated 4 times. Conservation agriculture treatments received 2t/ha of maize stover applied at the beginning of the season. Conventional tillage system had no residues applied. Agronomic management: all treatments received a basal application of phosphorous as triple superphosphate and potassium as muriate of potash both at 60kg per ha. Urea was applied at the rate of 60kgN/ha with 1/3 of NU applied at planting and 2/3 applied when maize was at knee high. CRU was applied at once at planting. The treatments tested were:

1. Conservation agriculture + normal urea (CA+NU)
2. Conservation agriculture + Controlled release urea (CA+CRU)
3. Conventional tillage + normal urea (CT+NU)
4. Conventional tillage +Controlled release urea (CT+CRU)

Data collection and analysis

Soil was sampled at 0 to 10cm, 10 to 25cm and 25 to 50cm depths at different days after planting for mineral N determination. Soil mineral N; ammonium (NH4+) and nitrate (NO3-) concentrations were determined calorimetrically. Maize was harvested at physiological maturity and yield was determined at 13 % moisture content.

Data for soil mineral N concentrations and maize yield was analyzed using Genstat Version 15. Significance differences between treatments (P=0.05) was tested and means separated using Fishers unprotected Least Significant Difference (LSD) test.

Results and Discussion

Soil nitrogen mineralization

Early in the season, nitrate concentration was significantly lower for CA+NU and CT+CRU across all soil depths while CA+CRU had the highest concentration (table 1). Later in the season the concentration was similar for all treatments, though the concentrations were generally higher for conventional tillage systems at harvesting time. Across all soil depths, ammonium concentration levels were generally lower in conventional tillage system than in conservation agriculture. Irrespective of the treatment, nitrate concentration was lower at harvesting than early in the season.

Table 1. Soil mineral nitrogen as influenced by urea type under conservation and conventional tillage systems in Siaya County

	Soil mineral N (g/kg) at different sampling dates and soil depths								
	Nitrate-N					Ammonium-N			
Treatment	13DAP	16DAP	55DAP	At harvest		13DAP	16DAP	55DAP	At harvest
			Depth (0 to 10cm)						
CA+NU 7.3^{d}	6.7^{b}	2.0^{a}	5.8^{a}	2.0^{a}	1.2^{ab}	1.4^{a}	1.0^{a}		
CA+CRU	10.1^{a}	9.7^{a}	2.3^{a}	4.8^{a}	1.7^{a}	2.0^{a}	1.2^{a}	1.0^{a}	
CT+NU 8.2^{b}	10.7^{a}	2.3^{a}	7.9^{a}	1.3^{a}	1.3^{b}	1.8^{a}	1.1^{a}		
CT+CRU	7.6^{c}	9.0^{ab}	2.3^{a}	6.6^{a}	1.6^{a}	1.0^{b}	1.2^{a}	1.1^{a}	
PVALUE	<0.001	0.03	0.66	0.09	0.3	0.05	0.1	0.8	
SED 0.1	1.1	0.3	1.1	0.8	0.3	0.3	0.2		
			Depth (10 to 25cm)						
CA+NU 11.9^{b}	12.1^{a}	2.4^{a}	6.6^{a}	2.2^{a}	2.0^{a}	1.1^{a}	0.9^{a}		
CA+CRU	13.8^{a}	10.5^{a}	3.0^{a}	5.0^{b}	1.6^{a}	2.9^{a}	1.3^{a}	0.9^{a}	
CT+NU 15.1^{a}	12.9^{a}	3.0^{a}	6.6^{a}	1.8^{a}	2.5^{a}	1.3^{a}	0.8^{a}		
CT+CRU	10.0^{c}	14^{a}	2.2^{a}	6.3^{ab}	1.0^{c}	1.7^{a}	1.3^{a}	0.9^{a}	
PVALUE	<0.001	0.6	0.3	0.03	<0.001	0.6	0.8	0.2	
SED 1.7	2.6	0.5	0.7	0.2	0.9	0.3	0.1		
			Depth (25 to 50cm)						
CA+NU 6.1^{b}	10.1^{a}	6.0^{a}	4.5^{c}	1.8^{a}	2.0^{a}	2.3^{a}	1.4^{a}		
CA+CRU	11.5^{a}	8.4^{a}	6.2a	5.0^{bc}	1.8^{a}	2.9^{a}	2.3^{a}	1.3^{a}	
CT+NU 8.9^{ab}	12.1^{a}	4.9^{a}	6.6^{ab}	-	2.5^{a}	2.2^{a}	1.8^{a}		
CT+CRU	6.7^{b}	11^{a}	4.1^{a}	6.3^{ab}	1.4^{a}	1.7^{a}	1.5^{a}	1.7^{a}	
PVALUE	0.01	0.1	0.3	0.03	0.6	0.6	0.3	0.6	
SED 1.3	1.3	1.2	0.7	0.2	0.9	0.4	0.4		

Means followed by similar letter are not significantly different at P = 0.05; DAP (days after planting), CA+CRU (conservation agriculture + controlled release urea), CA+NU (Conservation agriculture + normal urea), CT+NU (Conventional tillage + normal urea), CT+CRU (Conventional tillage + controlled release urea)

Excessive nitrate concentration in the soil early in the season when the crop is still very young usually leads to N losses (Shaviv, 2001). This is because at this stage the crop's nitrogen demand is low and the root system is not fully developed for N uptake. CRU fertilizer is designed such that nitrogen is released to the soil when crop demand is high thereby reducing losses but optimizing its uptake (Trenkel, 2010). We observed in this study a significantly lower nitrate concentration in CT+CRU and CA+NU treatments at the beginning of the season across all soil depths. As expected, the concentrations of both nitrates and ammonium decreased by the time of harvesting either because N was taken up by the crop (Fierer and Schimel, 2002), or was lost through leaching (Giller *et al*., 2011).

Maize yields

Maize grain yields were similar for CA+NU and CA+CRU (1.6 t/ha) while CT+NU and CT+CRU attained 1.7 t/ha each (table not shown). The differences in maize grain yield were not significant at p=0.05. Despite CT+CRU and CT+NU showing a significant lower nitrate concentration in the early days after planting, our study did not observe higher yields. This observation was similar to that of Venterea et al (2011) who observed no differences in maize yield after application of different urea types in Minnesota. However, the CA systems had lower maize yield compared to CT, but this could be attributed to N immobilization which is common with CA systems (Verachtert *et al*., 2009).

Conclusions

Although the concentration of nitrate was significantly lower early in the season (13 days after planting) for the CT+CRU compared to the CT+NU, there was no observed difference in maize yields between the two treatments. Similar observation where CA+NU had lower nitrates concentrations early in the season but no difference in yield over the CA+CRU indicates that the envisaged benefit of CRU was not realized in this study. Further studies with CRU especially at different rates of application should be carried out before ruling them out as such studies are minimal in Kenya.

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