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Abstract

A study was conducted to monitor the dynamics of available soil phosphorus (P), soil microbial biomass carbon (SMBC), nitrogen (SMBN), ammonium and nitrate nitrogen under seven Urochloa grass cultivars at Kitale, Kenya. The Urochloa cultivars: *Urochloa brizantha* cvs. Marandu, MG-4, Piata, Xaraes, *U. decumbens* cv. Basilisk, *U. hybrid* cv. Mulato II and *U. humidicola* cv. Llanero was compared with two popularly grown forages, Rhodes grass (*Chloris gayana* cv. KAT R3), Napier grass (*Pennisetum purpureum* cv. KK1) and annual weeds. The treatments were tested in a randomized complete block design arranged in a split plot treatment structure with two rates of fertilizer N (0 and 100 kg N $ha^{-1}yr^{-1}$) and P (0 and 40 kg P ha^{-1}) assigned to the main plots and the grass cultivars assigned to the subplots. After 80 weeks, moist rhizosphere soil was sampled at 0 – 10 cm depth to determine microbial biomass. Application of fertilizer N and P did not significantly (P>0.05) influence SMBC, SMBN, ammonium N (NH_4^+N) and nitrate N (NO_3^-N). However, significant (P= 0.001) changes in soil properties, including NH_4^+N and NO_3^-N due to grass cultivars, were observed. After 80 weeks, the bare plot, annual weeds and Napier grass accumulated higher pools of ammonium and nitrate N, but the microbial biomass (SMBC and SMBN) in these treatments were lower than in *Urochloa* grasses. Soil pH was also low, while NO_3^-N was high indicating increased nitrification in the bare and Napier grass plots. Ammonium N was the most dominant form of inorganic N in Llanero and Piata due to increased plant uptake or reduced nitrification rates. The results suggested that the change in the SMBC and SMBN in the Urochloa grasses was regulated by the nitrate and ammonium N and soil pH.

Key words: Ammonium N, microbial biomass N, nitrate, soil organic matter, soil quality

Introduction

Continuous cultivation of land for crop production has generally altered key soil nutrient cycles especially nitrogen (N), and phosphorus (P) in Kenya. Sustainable management of soil by increasing or maintaining organic matter content is essential for increased pasture productivity. Changes in organic matter input or rate of decomposition are more readily determined from soil microbial biomass than the total organic matter (Powlson et al. 1987). Assessment of soil microbial biomass indicates the impact of land use and management changes. Several authors have shown that the soil microbial biomass is higher in grass systems than in the open cultivated cropland because of the high turnover in pasture systems (McGonigles and Turner 2017). The dynamics of soil microbial biomass carbon (SMBC) and N (SMBN) have been used to determine the influence of different cropping systems on soil quality (Wu 2020). A study in Chinese sandy grasslands showed that addition of N over 5 years did not increase the soil organic C, total N and total P, but decreased soil pH, leading to lower microbial biomass (Li *et al*. 2010). Although several studies have shown changes in SMBC and SMBN in cropping and grassland systems, information on the contribution of different grass varieties to soil quality is scanty. Urochloa grasses are productive and persistent even under low soil fertility conditions, but information of the effect of growing these grasses in low fertility soils is scanty. This study, conducted in a low fertility Acrisol in Kenya monitored the dynamics of NO_3^-N, NH_4^+, SMBC and SMBN in different Urochloa grass cultivars under varying N and P management.

Methods and Study Site

The trial was conducted at the Kenya Agricultural and Livestock Research Organization (KALRO), Kitale, (1° 0′ 6.6′′N and 34° 59′ 10′′E) located within the sub humid highlands of Kenya. Seven *Urochloa* grass cultivars; *Urochloa decumbens* cv. Basilisk, *U. brizantha* cvs. Marandu, MG4, Piata, Xaraes, *U. hybrid* cv.

Mulato II *and U. humidicola* cv. Llanero, two commonly grown grasses Rhodes grass (*Chloris gayana* cv. KAT R3) and Napier grass (*Pennisetum purpureum* cv. KK1) were included as positive controls, while a bare and annual weeds plot as negative controls. Treatments were applied to plots in a randomized complete block design and assigned in a split plot structure with four replications. The main plot treatment was a level of N (0, and 100 kg N ha^{-1} yr^{-1}) and P (0 and 40 kg P ha^{-1}) fertilization while the grasses were assigned to the subplots. Triple superphosphate applied at the trial initiation provided P while calcium ammonium nitrate applied seasonally provided N. At 80 weeks after seedlings emergence, moist rhizosphere soil was sampled at 0 - 10 cm depth for determination of microbial biomass. Roots were sampled using the soil-core method (Bohm 1979) and root biomass calculated as a factor of the bulk density. The SMBC was determined by a fumigation extraction method according to (Vance *et al.* 1987) . The SMBN was determined using Brookes *et al.* (1985) , while NH_4^+N and NO_3^-N were determined as highlighted by Anderson and Ingram (1993). All measurements were analysed in triplicates and expressed as dry weight. Analysis of variance for split plot structure ($p < 0.05$) was undertaken to determine the effect of fertilizer N and P on microbial biomass, soil pH and available P using Statistix 10 package (Statistix 2003). Means were separated using the Tukey's HD test. Where ANOVA was significant ($P \leq 0.05$), Pearson correlation was performed to assess relationships between the soil microbial biomass, N and available P.

Results

Table 1 shows the effect of Urochloa grass on available P and soil microbial properties. Basal application of P and seasonal topdressing with N did not significantly ($p \leq 0.05$) influence the SMBC, SMBN, available P and NH_4^+N in soil. The available P accumulated in the soil was variable, with no differences among the grass varieties. The SMBC and SMBN were generally higher in the *Urochloa* grasses than in the controls (bare plot, annual weeds, Rhodes and Napier grass). Within the trial period, the SMBN accumulated in the soil was lower (91-124 mg N/ kg soil) than that reported (121 - 200 mg N/ kg soil) in the eastern drylands, Kenya by Gichangi *et al.* (2016). Llanero, Marandu and Piata accumulated lower NO_3^-N compared to NH_4^+N with higher NH_4^+N: NO_3^-N ratio and increased soil pH (6.05 – 6.12). The NH_4^+-N:NO_3^-N ratio compares the level of NH_4^+ N to each NO_3^-N accumulated in the soil. A high NH_4^+N compared to NO_3^-N ratio shows increased NH_4^+ N accumulation by the corresponding cultivar. The bare plot, Basilisk, MG-4, Mulato II, Xaraes, Rhodes and Napier grass had lower NH_4^+N:NO_3^-N ratio and lower soil pH showing higher conversion of ammonium to nitrates. Other cultivars such as Llanero, Marandu and Piata had accumulated lower NO_3^-N compared to NH_4^+N with higher NH_4^+N: NO_3^-N ratio that may indicate lower nitrification.

Table 1: Soil microbial biomass C and N, Ammonium and nitrate N under N and P fertilized Urochloa grasses in Kitale

Treatments	Microbial biomass C (mg C/ kg_{soil})	Microbial biomass N (mg N /kg_{soil})	NH_4^+N (mg N/kg)	NO_3^-N (mg N/kg)	Shoot: root ratio	Available P (ppm)
Bare plot	103	7.4	13.4	13.9	0	15.0
Annual weeds	107	7.6	10.2	8.6	1.7	19.2
Basilisk	91	5.6	8.1	6.6	3:1	16.7
Llanero	128	9.6	12.1	4.7	1:1	16.7
Marandu	121	9.3	8.9	4.2	2.5:1	17.5
MG4	102	7.1	9.6	7.6	3.6:1	15.8
Mulato II	124	9.2	6.9	5.4	2:1	16.7
Piata	110	8.0	9.6	4.9	2.5:1	15.0
Xaraes	113	8.2	7.3	4.9	2.9	13.8
Rhodes grass	114	5.5	9.5	7.5	4.2	14.2
Nappier grass (KK1)	111	5.9	11.2	8.4	6.0	18.3
Mean	111.3	7.5	9.70	6.98	-	16.25
SED $_{cv}$ (P=0.05)	Ns	Ns	1.85	1.85	-	ns

Where ns- not significant at $P \leq 0.05$

The significant negative relationship between SMBC and NH4+N and NO3-N was noted, suggesting that NH4+N and NO3-N decreased with an increase in microbial biomass (Table 2). However, the root biomass did not influence microbial biomass and soil nutrients. NH_4^+N and NO_3^-N were significantly ($P = 0.034$) influenced by the grass cultivars. The pools of NH_4^+N and NO_3^-N were higher in the bare plot, annual weeds and Napier grass which also accumulated lower SMBC. Ammonium N was the most dominant form of inorganic N in Llanero, Marandu and Piata. These cultivars also had lower NO_3^-N, SMBC and SMBN, indicating either low nitrification rates or a high rate of NO_3^-N uptake by plants.

Table 2 Pearson correlation between microbial biomass and root biomass in Kitale

	NH_4^+N	NO_3^-N	pH	P	SMBC	SMBN	RB
NO_3^-N	0.65*	1					
pH	-0.44	-0.84***	1				
P	0.135	0.02	0.16	1			
MBC	-0.68*	-0.69*	0.66*	-0.07	1		
MBN	-0.79**	-0.52	0.60*	-0.03	0.83**	1	
RB	-0.11	-0.45	0.02	-0.31	0.17	-0.09	1

Where * - $P \leq 0.05$; NH_4^+N - Ammonium N; pH- Soil pH; NO_3^-N – Nitrate N; P – Available P; SMBC- soil microbial biomass C; SMBN- soil microbial biomass N; RB- Root biomass sampled at 80 weeks after emergence

Discussion [Conclusions/Implications].

As a source and sink for plant nutrients, soil microbial biomass has been proposed as a sensitive indicator of changes in soil properties (Nannipieri et al. 2003). The availability of organic C, the primary source of nutrients for microorganisms, influences the size of microbial biomass C and N. In this study, all the shoot biomass was cut and removed from the plots to mimic the common practice of cut and carry forage management system, suggesting that root exudates contributed to SMBC. Hence, the differences in SMBC and SMBN accumulated by the grass cultivars were minimal. Lower decomposition rates in this humid climate reduced the amount of SMBC and N accumulated in the grasses compared to the levels reported in warm climates by Gichangi *et al.* (2016).

Nitrification is a biological process that converts NH_4^+N to NO_3^-N, creating acidification in the process as noted in the bare, Mulato II, Napier and Rhodes grass plots. The current study suggests that the grasses with lower NH_4-N:NO_3-N did not inhibit nitrification in the rhizosphere, contributing to higher N losses through leaching and denitrification. Llanero was the most effective in improving soil pH, probably from suppression of nitrification, confirming the results by Ishikawa et al. (2003). To minimize nitrification and reduce N loss in agricultural or pasture areas, it is necessary to maintain soil N in the form of NH_4^+N for as long as possible to synchronize N fertilizer supply and the plant demand (Ishikawa et al. 2003). Fernandes et al. (2011) obtained similar results, who reported increased NO_3-N and lower or similar levels of NH_4^+-N in *U. decumbens* and *U. ruziziensis*. Authors such as Sylvester-Bradley et al. (1988) and Ishikawa et al. (2003) also observed that *U. decumbens* do not inhibit nitrification as reported for *U. humidicola.* In conclusion, our study showed that when low levels of N and P is applied in low fertility soils, the *Urochloa* varieties did not accumulate significant SMBC, SMBN and available P. However, Llanero accumulated higher ammonium in the soil, implying reduced losses of the highly mobile NO_3^-N. The results in this study suggested that the change in the SMBC and SMBN in the Urochloa grasses was regulated by the nitrate and ammonium N and soil pH. Further study is suggested to test the effects of retention of shoot biomass on SMBC and SMBN and other soil properties in this humid region.

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References

Anderson, J. M. and Ingram, J. S. 1993. Tropical Soil Biology and Fertility: A Handbook of Methods. CAB International, Wallingford, England.

Bohm, W. 1979. Methods of studying root systems. *Ecological studies* 33.

Brookes, P. C., Landman, A., Pruden, G., and Jenkinson, D. S. 1985. Chloroform fumigation and the release of soil nitrogen: a rapid direct extraction method to measure microbial biomass nitrogen in soil. *Soil Biol Biochem* 17: 842.

Fernandes, A. M., AndradeII, G. J. M., Souzall, E. F. C., and Rosolem, C. A. 2011. Brachiaria species affecting soil nitrification. *The Revista Brasileira de Ciência do Solo* 35: 1699-1706-1706.

Gichangi, E. M., Njarui, D. M. G., Gatheru, M., Magiroi-Ndungu, K. W., and Ghimire, S. R. 2016. Effects of Brachiaria grasses on soil microbial biomass carbon, nitrogen and phosphorus in soils of the semi arid tropics of Kenya. *Tropical and Subtropical Agroecosystems* 19: 193-203.

Ishikawa, T., Subbarao, G. V., Ito, O., and Okada, K. 2003. Suppression of nitrification and nitrous oxide emission by the tropical grass *Brachiaria humidicola*. *Plant and soil* 255: 413-419.

Li, L. J., Zeng, D. H., Yu, Z. Y., Fan, Z. P., and Mao, R. 2010. Soil microbial properties under N and P additions in a semi arid, sandy grasslands. *Biology and Fertility of Soils* 46: 653-658.

McGonigles, T. P. and Turner, W. S. 2017. Grasslands and Croplands Have Different Microbial Biomass Carbon Levels per Unit of Soil Organic Carbon. *Agriculture* 7: 57-65.

Nannipieri, P., Ascher, J., Ceccherini, M. T., Landi, L., Pietramellara, G., and Renella, G. 2003. Microbial diversity and soil functions. *European Journal of Soil Science* 54: 655-670.

Powlson, D. S., Brookes, P. C., and Christensen, B. T. 1987. Measurement of soil microbial biomass provides an early indication of changes in total soil organic matter due to straw incorporations . *Soil Biology and Biochemistry* 19: 159-164.

Sylvester-Bradley, R., Mosquera, D., and Mendez, J. E. 1988. Inhibition of nitrate accumulation in tropical grassland soil: Effect of nitrogen fertilization and soil disturbance. *European Journal of Soil Science* 39: 407-416.

Vance, E. D., Brookes, P. C., and Jenkinson, D. S. 1987. An extraction method for measuring soil microbial biomass C. *Soil Biology and Biochemistry* 19: 703-707.

Wu, J. 2020. Change in soil microbial biomass and regulating factors in an alpine meadow site on the Qinghai-Tibetan Plateau. *Soil Science and Plant Nutrition* 66: 177-194.