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Effect of inorganic fertilizers on forage yield, accumulation of carbon, nitrogen and phosphorus in sudangrass (*Sorghum sudanense*) and ryegrass (*Lolium multiflorum*) cropping system in Central China

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ABSTRACT

The sudangrass *(Sorghum sudanense*) and ryegrass *(Lolium multiflorum* L.) rotation is a new type of cropping system in central China. A field study of effects of inorganic fertilizers (NPK) on yield of forage, accumulation of C, N and P in grass and soil fertility in this rotation was conducted through a four-year field experiment from April 2005 to May 2009. The treatments consisted of control (CK), fertilizer P and K (PK), fertilizer N and K (NK), fertilizer N and P (NP) and fertilizer N, P and K combination (NPK). For four years, proper fertilization (NPK treatment) increased yield of sudangrass and ryegrass by 17.2%–23.1% compared to the NP treatment, increased by 20.2%–26.8% compared to the NK treatment, and were 2–4 times higher than that of CK and PK treatments. The accumulation of C, N and P in NP (fertilizer N, P), NK (fertilizer N, K) and NPK (fertilizer N, P, K) treatments were 118.8%–173.5%, 269%–468% and 48.7%–157.5% higher than those of the CK treatment, respectively, while PK treatment was similar to CK treatment. At the end of the experiment, organic C, total N and P in soil in the NPK treatment were 14.6%, 18.4%, 36.6% higher than those of the CK treatment, respectively. The proper combination of NPK fertilizers could assure crop yield and sustainable soil productivity

Key word: NPK combination, Soil organic C, Sudangrass and ryegrass rotation, Yield

Major increase in livestock products will be required to meet the future demand for food worldwide (Tilman *et al*. 2002). With increasing population, the intensive system was adopted to produce more forage production for livestock (Conelly *et al.* 2000). It is essential to consider the longer term interactions between food security and healthy land resource, and the application of fertilizers has been widely recommended for forage production in the intensive system (Hossain *et al*. 2000; Chakraborty *et al*. 2010).

Soil organic C, total N and total P are important chemical indicators for soil fertility changes. Soil organic C is a key component, and had important effects on many of the processes that occur within the agricultural system (Galantini and Rosell 2006). Fertilization affected the content of soil organic C in agricultural soils through crop residue production and the increase of aboveground and belowground biomass due to fertilization resulted in improving the organic C pools in soil (Franzluebbers *et al*. 2000, Saha *et al*. 2010).

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Total N and total P are also important components of soil fertility for sustainable agricultural production (Russell *et al*. 2006). The increase of total N and P in soil due to fertilization also resulted in maintaining soil fertility (Shen *et al.* 2004).

Sudangrass (*Sorghum sudanense*) and ryegrass *(Lolium multiflorum* L.) C_4 species and C_3 species, respectively, are the important forage grasses for livestock and fish in China. The sudangrass and ryegrass rotation attains good growth and provide higher biomass and thus it has become a new type of cropping system in Central China (Lu *et al*. 2003). Because of higher biomass in the system, nutrients uptake of forage grasses were higher (Lu *et al*. 2003, 2004). Therefore, it is necessary for proper nutrient supplementation to obtain sustainable forage biomass and healthy soil productivity. Hence, the present study was conducted with the objectives to study the effect of NPK fertilization on yield of forage grass through four-year established experiment and to assess the variation of soil fertility with different nutrient schedule in the sudangrass and ryegrass rotation system.

MATERIALS AND METHODS

The field experiment was established at the Agricultural

Research Station of Datonghu Administration District, Jingzhou City, Hubei province, China (30°32 N, 113°452 E). The climate of the experimental site is warm and moist, average annual temperature is –3.5!–38.6!, and the average annual precipitation was 1200 mm. The soil was derived from alluvial sediments of Yangtze River and classified as fluvio-aquatic soil. In the original soil, soil *p*H (1:2.5 water: soil) was 6.93, and contained organic C 10.7 g/kg, total N 1.05 g/kg, total P 0.79 g/kg, extractable P 12.0 mg/kg, available K 121.7 mg/kg.

The four-year established field experiment of sudangrass *(Sorghum sudanense* cv. Yanchi) grown in summer and ryegrass *(Lolium multiflorum* cv. Abundant) grown in winter was conducted in Jianghan Plain during April 2005–May 2009. Each year, sudangrass and ryegrass were directly broadcast sowing in each plot, with seed rate of 112.5 kg/ha and 37.5 kg/ha, respectively. Numbers of harvests in sudangrass in summer (May–September) were 5, 4, 5 and 5, respectively. In case of ryegrass, numbers of harvests were 3, 4, 4 and 4 during winter (October – April), respectively.

The experiment was laid out in a randomized block with four replications in plot measured 7.5 m×2 m. The treatments consisted of control (CK), fertilizer P and K (PK), fertilizer N and K (NK), fertilizer N and P (NP) and fertilizer N, P and K combination (NPK). Based on the previous research (Lu *et al*. 2003 and 2004), the rates of applied fertilizer were applied in the sudangrass (N 450, P_2O_5 180 and K_2O 300 kg/ha) and ryegrass (N 225, P_2O_5 135 and K_2O 150 kg/ha) rotation. In sudangrass, one-third of fertilizer N and half of fertilizer K were applied as basal dressing, and the rest were applied for top-dressing in three times While in ryegrass, half of fertilizer N and K were applied as basal dressing, the rest for top-dressing in two times. Nutrients were supplemented through urea, calcium superphosphate and potassium chloride for N, P and K doses, respectively.

Before each harvesting during 2008–09, fresh grass samples were taken, weighed, deactivated for half an hour at 105°C, dried 48 hr at 60°C and weighed for dry sampling, ground and then stored in the sealed bags for C, N and P analysis. Forage C was determined by the oxidation method with $K_2Cr_2O_7$ and concentrated sulfuric acid at 170–180°C and total nitrogen by the regular Kjeldahl method, Total P were digested in $HClO_4$ and H_2SO_4, and P was determined by the Spectrometer (Bao 2000).

After each season ended, soil samples were taken from 0–20 cm top layer in each plot, and used for the testing of soil organic C, total N and total P (Bao 2000).

Dry matter (tonnes/ha) = fresh grass yield (tonnes/ha) × (dry sampling/fresh sampling).

Nutrients accumulation by forage grass (kg/ha) = Dry matter tonnes/ha) ×1 000×nutrients content (% DM) /100.

The data was statistically analyzed using SPSS13.0 software package for Windows. Statistically significant differences were measured by analysis of variance (ANOVA) and least significant difference (LSD) calculations for fertilization × year at the 0.05 probability level.

RESULTS AND DISCUSSION

Forage yield

Yield of forage grasses was highly variable due to inorganic fertilizers during the experimental years of 2005–09 (Fig 1). Total yield in NP, NK and NPK treatments were significantly 156.4%–350.2% higher than that of CK and PK treatment *(P* < 0.05). Yield levels were highest in NPK treatment in each year with 162.7, 114.8, 145.6 and 126.0 tonnes/ha. Fertilizer N obtained the highest response, following by fertilizer P and fertilizer K. Forage yield also changed with cropping seasons (Table 1). Analysis of variance over four years showed significance (*P* < 0.05) of the main effects in the sudangrass and ryegrass rotation system. Yield variation over four years in NPK treatment was significant in each period *(P* < 0.05). There were also different for total yields of grasses in NP and NK treatments in each period with the variation of 4.4% –23.6%. In CK and PK treatments, total yield over four years were not statistically significant *(P* < 0.05). For NP, NK and NPK treatments, Yield of each year was different, especially yield in NPK treatment were significantly different *(P* < 0.05). It seemed that yield of forage grass with the application of fertilizers in soil were easier to be affected and changed greatly with years. Variation of crop yield was influenced by more factors including climate, management measures and the planting conditions (Anwar *et al.* 2007; Singh *et al.* 2010). Mussgnug (2006) reported that crop yield in intensive and rice-based cropping systems responded differentially to fertilizer treatments and cropping seasons. There were also some management measures and planting conditions to affect variation of yield (Chand *et al*. 2004) and these factors synthetically influenced the sustainability of crop yield.

Accumulation of nutrients in forage grass

Compared to the CK treatment (Table 2), total C accumulation of forage in the NP, NK and NPK treatments were 115.6%, 119.0%, 173.5% higher, respectively, especially NPK treatment was the highest in all treatments with 5.77 tonnes/ha for two seasons, and C accumulation in PK treatment was similar to CK treatment. Similar to C accumulation, N accumulation of forage in NP, NK and NPK treatments were also 307.7%, 270.3%, 370.3% higher than that in CK treatment

Table 1 Yield of forage in different years (tonnes/ha)

Period	CK	NP	NK	PK	NPK
2005–06	36.1a	138.0a	128.2a	39.4a	162.7a
2006–07	25.1a	97.9c	95.5b	26.1b	114.8d
2007–08	34.6a	119.6b	118.1a	43.9a	145.6b
2008–09	35.3a	102.3c	100.1b	39.0a	126.0c

Different letters in the same column indicate significant differences at $P < 0.05$

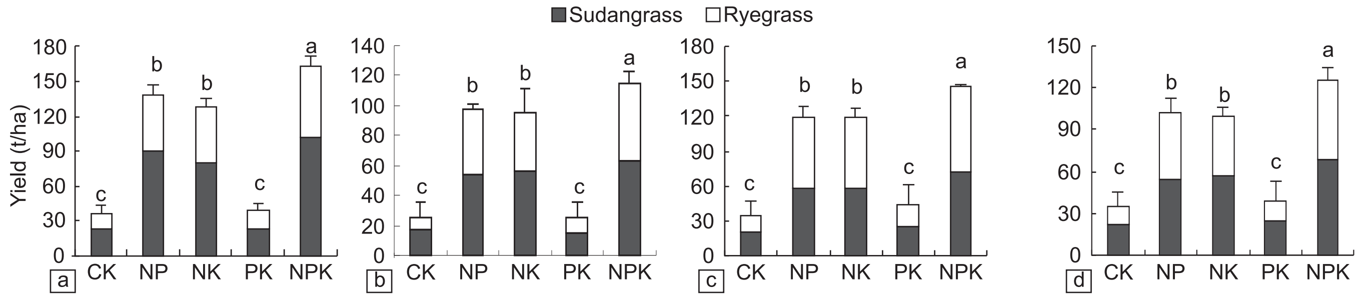

Fig. 1 Effect of fertilization on yield of sudangrass and ryegrass for four years. (a) Forage yields during 2005–06; (b) Forage yield during 2006–07; (c) Forage yield during 2007–08, (d) Forage yield during 2008–09. Small letter differences in the same figure mean significant difference at $P < 0.05$.

Table 2 Effect of fertilization on accumulation of C, N and P for forage grass

Treatment	C (tonnes/ha)			N (kg/ha)			P (kg/ha)		
	Sudangrass	Ryegrass	Total	Sudangrass	Ryegrass	Total	Sudangrass	Ryegrass	Total
CK	1.40c	0.71c	2.11c	48d	43c	91c	18c	10c	28d
NP	2.95b	1.80b	4.76b	153b	218ab	371b	27b	34a	60b
NK	3.05ab	1.57b	4.62b	156b	181b	337b	27b	14b	42c
PK	1.28c	0.77c	2.04c	72c	46c	118c	24bc	12bc	36cd
NPK	3.63a	2.14a	5.77a	190a	237a	428a	37a	35a	72a

Different letters in the same column indicate significant differences at $P < 0.05$

(Table 2). Total P accumulation in NPK treatment was the highest in all treatments with 72 kg/ha (Table 2), and was following by NP treatment, and P accumulation in NK treatment without P application in soil was also 50% higher than that in CK treatment. These results are in line with those of Gouis *et al*. (2000) and Kumar *et al*. (2011).

Soil organic C, total N and P

In the end of experiment (Fig 2a), and organic C in soil with fertilizers was 8.1%-14.6% higher than that of CK treatment, but there was not statistically significant ($P < 0.05$). After sudangrass and ryegrass rotation growth, soil organic C in all treatments also increased by 13.6%–30.1% compared to the original soil with 10.7 g/kg. It was possible that root residues in the rotation system entered into the soil and resulted in the increase of soil organic C. Sherrod (2003) showed the increase of soil organic C resulted from the greater amounts of biomass in the intensive agroecosystems. Aboveground and belowground biomasses in agroecosystems were systematically integrated, and there were a positive relationship between energy exchange and nutrients cycling of aboveground and belowground biomass (Galantini and Rosell 2006; Rasool *et al*. 2007).

Total soil N in the system is shown in Fig 2b. Compared to the CK treatment, total soil N in NP, NK and NPK treatments were 18.4%–26.2% higher than that of CK treatment, while PK treatment was similar CK treatment. After sudangrass and ryegrass rotation growth, total N in

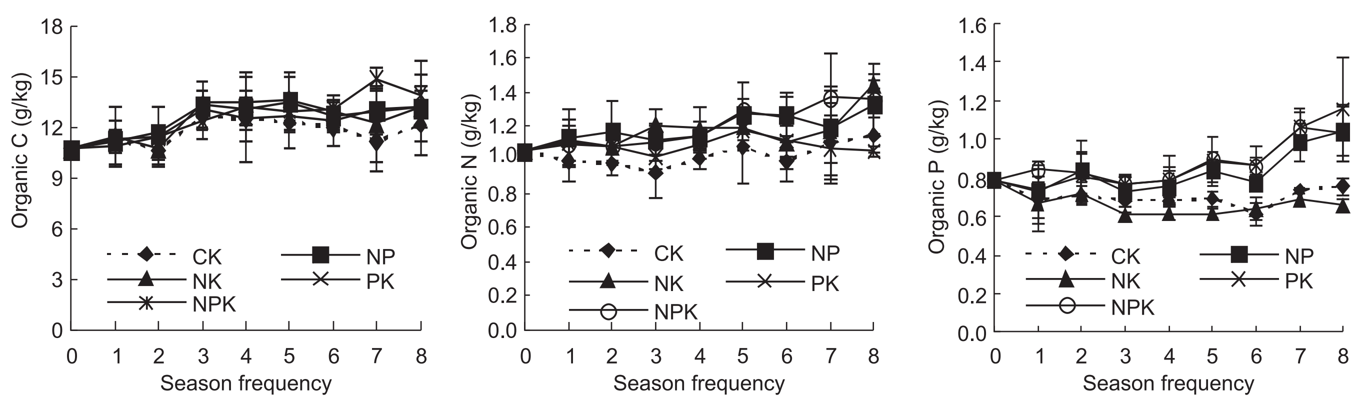

Fig 2 Effect of fertilization on soil organic carbon, total N and P in the rotation system. (a) Soil organic carbon, (b) Total soil N, (c) Total soil P. "1", "2", "3", "4", "5", "6", "7" and "8" mean harvest frequency. The line means standard error of all treatments.

NP, NK and NPK treatments increased by 28.8%–37.3% compared to the original soil. It was previously reported that fertilizer N could increase N pool in soil and improve soil fertility (Russell *et al.* 2006). However, in our experiment, total soil N in PK treatment was similar to CK treatment, and was basically stable in PK and CK treatments compared to the original soil. Soil N in pools partially came from precipitation, runoff and crop residues (Manzoni *et al.* 2008). It was possible that the crop residues and rain in the sudangrass and ryegrass rotation maintained the N balance in pools without the application of N fertilizer in soil.

Total soil P in NP, PK and NPK treatments were also 36.6%–52.9% higher than that in CK treatments (Fig.3c), and total soil P in NK treatment was the lowest in the system. After sudangrass and ryegrass rotation growth, total P in NP, PK and NPK treatments increased by 30.7%–46.3% compared to the original soil. It was also reported that fertilizer P maintained P balance or built-up soil P pools, but P-omitted application increased soil P depletion compared with the no-fertilizer treatment (shen *et al.* 2004).

The sudangrass and ryegrass rotation was an intensive cropping system in Central China. In this cropping system, the combination of N, P and K fertilizers increased yield of forage grass, C, N and P accumulation aboveground biomass of grass and maintained soil fertility, i e the increase of soil organic C, total N and P.

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