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Original article

Soil macrofauna affect crop nitrogen and water use efficiencies in semi-arid West Africa

E. Ouédraogo[a,*], A. Mando[b], L. Brussaard[c]

[a] *Département Agroécologie, Centre Ecologique Albert Schweitzer, Burkina Faso (CEAS-BF), 01 P.O. Box 3306, Ouagadougou 01, Burkina Faso*
[b] *International Centre for Soil Fertility and Agricultural Development (IFDC), Division Afrique, P.O. Box 4483, Lomé, Togo*
[c] *Department of Soil Quality, Wageningen University, P.O. Box 8005, 6700 EC Wageningen, The Netherlands*

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Abstract

It is increasingly recognised that soil fauna have a significant role in soil processes affecting nutrient availability and crop performance. A field experiment was conducted in southern Burkina Faso (West Africa) to investigate the contribution of soil fauna to nutrient availability and crop performance after application of different organic materials with contrasting qualities. A split plot design with four replications was laid out. The main treatment was the use of insecticides, to establish plots without fauna next to plots with fauna. The sub-treatments consisted in the application of *Andropogon* straw, cattle dung, maize straw, compost or sheep dung and a control. Soil fauna significantly increased crop water use efficiency. Crop nutrient use efficiency was high with the use of easily decomposable organic material in the presence of soil fauna. Supplementing low quality organic resources with mineral nitrogen is required to optimise the effects of their interaction with soil fauna towards enhanced crop nutrient and water use efficiencies.

Keywords: Soil fauna; Nutrient use efficiency; Water use efficiency; Burkina Faso

1. Introduction

In semi-arid West Africa, efficient use of water and nutrients by the crop is essential to sustain agricultural production. Previous studies showed that soil fauna can play a key role in nutrient and water availability to crops [4,2]. In the savannah ecosystem of Kaibo soils are characterised by low organic matter content and nitrogen and phosphorus limitations. The cropping system is largely dependent on nutrient release by organic resource decomposition and, therefore, the activities and interactions of soil fauna. Soil macrofauna mainly consist of termites (78%), ants, Coleoptera, Myriapoda, Arachnida, Dermaptera and earthworms [5]. The application of organic resources plays a key role in West African agricultural systems where little or no mineral fertiliser input is used. In this region, continuous and intensive cropping without restitution has depleted the nutrient base of most soils leading to negative nutrient balances [8,7,1]. This paper analyses how the beneficial effect of soil fauna on crop water and nitrogen use efficiency can be optimised with the use of organic resources with contrasting qualities.

2. Materials and methods

The study was conducted in 2000 in Kaibo (11–12°N) in southern Burkina Faso characterised by a north Sudanian climate. The annual rainfall ranges from 750 to 1000 mm with a mean temperature of 28 °C. The rainy season is from June to September with an average rainfall of 935 mm for the last 47 years. A split plot design with four replications was laid out in a site previously under fallow for 6 years. The experiment was laid out on a Eutric Cam-

* Corresponding author. Tel.: +226 50 34 3008; fax: +226 50 34 1065.
E-mail address: ceas-rb@fasonet.bf (E. Ouédraogo).

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bisol with a loamy texture (47% sand, 36% silt, 17% clay).

The main treatment was the use of insecticides, to establish plots with fauna and plots without fauna. Dursban (insecticide) (with chloropyrifos as active ingredient, applied at the rate of 400 g a.i. ha^{-1}) and endocoton (insecticide and acaricide) (with endosulfan as active ingredient, applied at the rate of 450 g a.i. ha^{-1}) were applied four times (just before the set-up of the experiment and 3, 6 and 10 weeks after the organic material application and sowing). Evaluation of pesticide effects on the main groups of soil macrofauna was done by Ouédraogo et al. [5]. The results showed that termite, earthworm and ant populations were reduced, respectively, by 99.6%, 100%, and 96.3% compared to untreated plots. The plots measured 24 × 20 m and were 10 m apart. Sub-treatments consisted of *Andropogon* straw, cattle dung, maize straw, compost and sheep dung application, equivalent to 40 kg N ha^{-1}, and a control plot without organic amendment. Organic amendments were applied at the soil surface. Compost was produced after aerobic decomposition. The size of sub-plots was 10 × 5 m, separated by guard rows of 2.5 × 2 m. The blocks were separated by an alley of 4 m.

The plots were sown with sorghum (*Sorghum bicolor* L. Moench) variety SARIASO 14 at a density of 31,250 seedlings ha^{-1} on July 2000. During the growing season the field was weeded twice using hoes. The crop was harvested 4 months after sowing.

Sorghum water use efficiency (WUE) was calculated as:

$$WUE = (\text{Total above ground biomass in the treatment} - \text{total above ground biomass in the control without fauna})\ (\text{kg/ha})/\text{Total rainfall (mm)}$$

Apparent nitrogen use efficiency (ANUE) was calculated as:

$$ANUE = (\text{Sorghum grain yield in the treatment} - \text{Sorghum grain yield in the control without fauna})\ (\text{kg ha}^{-1})/\text{Equivalent total nitrogen applied (kg ha}^{-1}).$$

3. Results and discussion

3.1. Sorghum nitrogen use efficiency

Soil fauna enhanced crop ANUE (Fig. 1) in the treatment with compost, sheep dung and maize straw but reduced ANUE in the treatment with *Andropogon* straw and cattle dung. Table 1 shows that soil fauna, organic amendments and their interaction significantly affected ANUE. The *F*-value indicates that soil fauna affected more ANUE than the type of organic amendment.

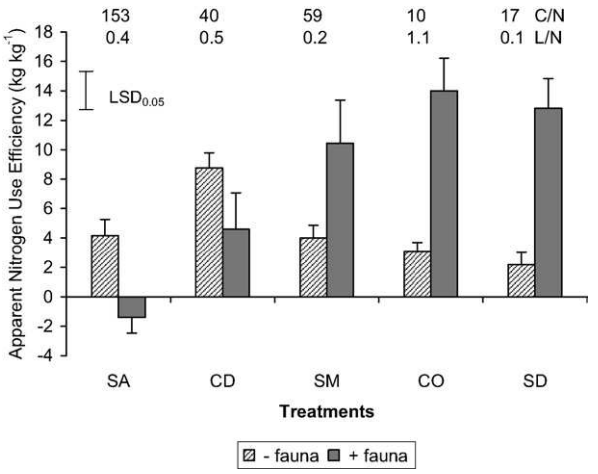

Fig. 1. Sorghum ANUE in fauna and no-fauna plots at Kaibo, Burkina Faso, after application of organic resources of different qualities. SA = *Andropogon* straw, CD = cattle dung, SM = maize straw, CO = compost, SD = sheep dung. Bars represent standard deviations. LSD = least significant difference at $P = 0.05$. C/N = carbon:nitrogen ratio, L/N = lignin:nitrogen ratio.

The reduction in ANUE should be due to stimulated nitrogen immobilisation in the presence of soil fauna. Indeed, recalcitrant organic material need to be broken down by soil macrofauna, which increases the exposure of substrate to the microflora, and lead to an enhanced decomposition [6]. In nitrogen-deficient soils enhanced decomposition of recalcitrant organic material leads to nitrogen immobilisation. These results indicate that soil fauna is essential to nitrogen use efficiency by crops in the low input agricultural systems in semi-arid West Africa but external nitrogen input is necessary to optimise nitrogen use efficiency with the application of low quality organic material.

3.2. Sorghum WUE

In semi-arid West Africa, water is one of the limiting factors for crop production. WUE was 1.5 kg mm^{-1} in

Table 1
ANOVA of apparent nutrient use efficiency (ANUE)

Source of variation	df	*F*-value	*P*-value
Soil fauna	1	401.15	< 0.001
Organic amendment	4	190.00	< 0.001
Soil fauna × organic amendment	4	383.06	< 0.001

P-value: probability level, df: degree of freedom.

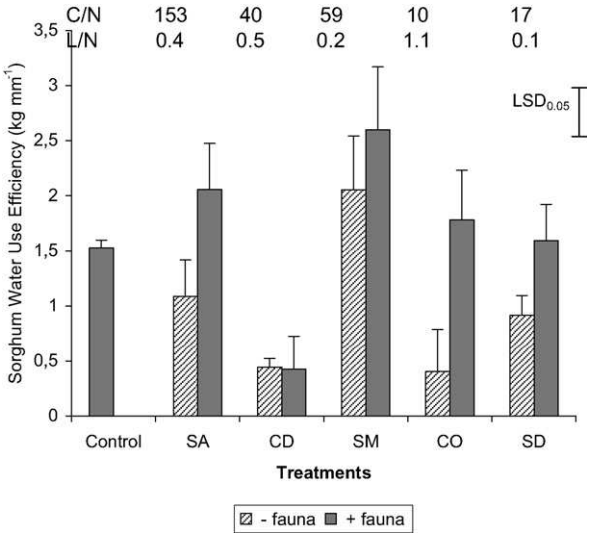

Fig. 2. Sorghum WUE in fauna and no-fauna plots at Kaibo, Burkina Faso, after application of organic resources of different qualities. Legend as in Fig. 1.

the plots with fauna (Fig. 2). Soil fauna significantly increased sorghum WUE except in the treatment with cattle dung. This may be due to the improvement of soil physical properties. Mando and Miedema [3] showed that in semi-arid area, soil fauna continuously open voids, which significantly improves soil water availability to the crop. Cattle dung had the highest L:N ratio probably because dung was collected at the end of the dry season a period where the quality of forage is very poor with high lignin content. The unavailability of nutrient may reduce sorghum WUE. The reduction of WUE in no-fauna plots underlines the key role of soil fauna in the improvement of crop WUE in semi-arid regions.

4. Conclusion

After the application of organic resources of high quality, crop water and nitrogen use efficiencies are significantly enhanced in the presence of soil fauna.

In the presence of soil fauna, the mulching effect of low quality organic material can improve crop WUE but may reduce crop nitrogen use efficiency due to increased nitrogen immobilisation. Supplementing recalcitrant organic material with inorganic nitrogen will optimise the beneficial impact of soil fauna on nutrient use efficiency. Agricultural practices that eliminate the beneficial contribution of soil fauna such as intensive soil tillage and pesticide application should be avoided especially in low input agricultural systems.

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