Impacts of long-term fertilisation on plant functional traits and diversity of grasslands on Reunion Island

Randrianarivony L.[1], Tillard E.[1], Rivière E.[1], Salgado P.[2], Blanfort V.[3], Lecomte P.[4] and Taugourdeau S.[4]

[1]CIRAD, Umr SELMET Livestock Systems in Tropical and Mediterranean Areas, Saint-Pierre, La Réunion, France; [2]CIRAD-SPAD Systèmes de production d'altitude et durabilité, Antsirabe, Madagascar; [3]CIRAD, Umr SELMET Livestock Systems in Tropical and Mediterranean Areas, Montpellier, France; [4]CIRAD, PPZS, Pôle Pastoralisme et Zones Sèches, Dakar, Sénégal

Abstract

On Reunion Island, grassland is the second agricultural land cover. Grasslands are present in the different ecological contexts of the island (from tropical at sea level to temperate climate on the mountain area). The fertilisation inputs are quite high. The long-term impacts of fertilisation on the vegetation have been studied mainly for temperate grasslands and impacts on tropical grasslands are not well known. The species pool is different in the diverse climates. The functional trait approach allows us to compare the dynamics of communities with different species. We studied the impact of fertilisation (quantity and type of inputs) on grassland communities along a climatic gradient. Since 2004, ten different treatments of fertilisation with three replicates (organic and/or mineral inputs from 0 to 600 kg N ha^{-1}) were applied on grassland in three different sites of the western part of Reunion Island (tropical site, temperate site and intermediate site). Three functional traits were measured: the specific leaf area (SLA), leaf dry matter content (LDMC) and vegetative height (H) in 2016. From these trait values, different variables were calculated (functional diversity, intraspecific variability indicators, etc.) and were compared between the different treatments and sites. The functional trait value was different between the three sites. The fertilisation affected only a few functional traits. These impacts were more important in the temperate climate than in the tropical one. This work contributes to our understanding of the long-term impact of fertilisation on the flora composition and can be used to propose adapted management of fertilisations (type or quantity).

Keywords: tropical permanent grassland, fertilisation, functional traits

Introduction

Reunion Island is a volcanic island in the Indian Ocean (21°05 south and 55°30 east). The climate on the island ranges from tropical at sea level to a temperate climate. The grasslands are the second-largest agricultural area of the island, comprising 20% of the agricultural area. The livestock density increased 60% during the period 1989 - 2010, resulting in increased fertiliser use. Most of the fertilisation on the Reunion Island is from mineral origin. This fertiliser induces several environmental drawbacks: water pollution, soil erosion, etc. Organic fertilisation is now suggested by different local institutions. To have a better understanding of the response of the grassland ecosystem, an experiment was installed in 2004 in three different agro-ecological sites at different elevations with ten fertilisation treatments. The experiment is still in progress. This paper presents the long terms impacts of these fertiliser applications on the grassland plant communities.

Materials and methods

The first site is characterised by a tropical climate (10 m a.s.l.) sandy soil and a dominate species *Chloris gayana*. The second site is localised at 800 m a.s.l. an intermediate climate (800 m a.s.l.) with andosol and the main grass species are *Pennisetum clandestinum and Paspalum dilatatum*. The high altitude of the third site (1,600 m a.s.l.) gives it a temperate climate and induces the dominant presence of temperate grasses such as *Dactylis glomerata, Bromus catharticus and Lolium arundinaceum.* These different plots were implemented by *Chloris gayana, Pennisetum clandestinum* and *Lolium perenne*. Ten treatments of fertilisation (Table 1) were applied with three replications on micro plots on each of the three sites. These micro-plots were of 6 m by 0.65 m. Each plot was cut around seven times per year.

On each of the 90 plots, we measured three functional traits for each species on five individuals at most. We measured the vegetative height on the field as the distance between the soil and the highly mature leaf stretched on the steam. This leaf is after sampled to measure leaf traits. The specific leaf area (SLA) was measured by the ratio between leaf area (measured on the fresh leaves) and the dry mass of the leaf. The leaf dry matter content (LDMC) was measured as the ratio between the dry and fresh mass of this last leaf. The field measurements were made in March for the two lower sites and in June 2016 for the highest sites just before the cuts. We compared the trait value per sites, per type of fertilisation, per N quantity, fertilisation treatment using ANOVA. We conducted a two-factor ANOVA to test the interactions between the site and the different treatments, quantity and type of fertilisations. Finally, we tested within each site the effect of treatments, type and quantity of fertilisation. The specific leaf area values were log transformed. Analyses were conducted using R core software.

Results and discussion

Table 2 presents the different results from the ANOVA. The functional traits were different between the sites. The individuals measured in the tropical climate condition had a higher height and LDMC and a lower SLA than those from the two other sites. The overall effect of the fertilisation treatment did not apply to all the variables. The LDMC was affected by the different treatment and the type of fertilisation. The results show also that the height was sensitive to the different fertilisation types. The interactions between sites and treatments were significant for most of the traits. On the tropical and intermediate site, the vegetative height was slightly affected by the type of fertilisation (plants were a little higher on mixed fertilisation). The vegetative height was affected by the different treatments only in the intermediate site with a higher height on mixed fertilisation. On the same site, the log SLA were affected by the type of fertilisation. On the temperate site, the LMDC was higher on the 0 input treatment compared to the other treatments. SLA and H were lower on the 0 input treatment.

Conclusion

Fertiliser application had different impacts on the functional traits on our three different sites. There were very few impacts on the tropical site and strong impacts on the temperate site. The long-term impact of fertilisation on temperate grassland on SLA and LDMC were already shown in the literature (Louault *et al.*, 2017; Marriott *et al.*, 2004).These results show the importance of the climate on the management of functional trait relationships.

Table 1. List of the different fertilisation treatments tested since 2014. The litter and the compost were from cattle.

Treatment	Description	Type	N quantity
T1	0 inputs		nil
T2	70 kg ha^{-1} yr^{-1} of N mineral	mineral	medium
T3	40 m^3 ha^{-1} yr^{-1} of litter	organic	medium
T4	40 m^3 ha^{-1} yr^{-1} of litter and 30 kg ha^{-1} yr^{-1} of N mineral	mixed	medium
T5	70 m^3 ha^{-1} yr^{-1} of litter	organic	high
T6	7.2 t.ha-1.yr-1 of compost	organic	high
T7	7.2 t ha^{-1} yr^{-1} of compost and 56 kg ha^{-1} yr^{-1} of N mineral	mixed	medium
T8	12 t ha^{-1} yr^{-1} of compost	organic	high
T9	12 t ha^{-1} yr^{-1} of compost and 48 kg ha^{-1} yr^{-1} of N mineral	mixed	high
T10	120 kg ha^{-1} yr^{-1} of N mineral	mineral	high

Table 2. Effects of the different treatments on the three functional traits, based on ANOVA. The values in bold indicate $P < 0.05$.

Site	Variables	Vegetative height	LogSLA	LDMC
All the site together	site	**0.00**	**0.00**	**0.00**
	fertilisation type	**0.05**	0.60	**0.00**
	nitrogen quantity	0.07	0.53	0.06
	treatment	0.22	0.28	**0.00**
	treatment*site	**0.00**	**0.00**	0.09
	quantity*site	**0.01**	**0.01**	**0.04**
	type*site	**0.04**	**0.00**	0.09
Tropical	fertilisation type	0.10	0.50	0.22
	nitrogen quantity	0.78	0.96	0.92
	treatment	0.06	0.40	0.52
Intermediate	fertilisation type	**0.03**	**0.00**	0.07
	nitrogen quantity	**0.00**	0.09	0.09
	treatment	**0.00**	0.10	0.24
Temperate	fertilisation type	**0.03**	**0.00**	0.07
	nitrogen quantity	**0.00**	0.40	**0.02**
	treatment	**0.00**	**0.00**	**0.00**

References

Louault F., Pottier J., Note P., Vile D., Soussana J.-F. and Carrère P. (2017) Complex plant community responses to modifications of disturbance and nutrient availability in productive permanent grasslands. *Journal of Vegetation Science* 28, 538-549.

Marriott C., Fothergill M., Jeangros B., Scotton M. and Louault F. (2004) Long-term impacts of extensification of grassland management on biodiversity and productivity in upland areas. A review. *Agronomie* 24, 447-462.