Temporal variations in the carbon and nitrogen ecological stoichiometry of lucerne

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Introduction

Ecological stoichiometry has been of great help in research investigating the coupling between plant and environment (Sterner and Elser 2002). It provides some synchronized evidence to explain the response and adaptability of plants to the environment. Carbon and nitrogen ecological stoichiometry (C/N) also embraces the use efficiency of nitrogen in plants. Previous research has focused on the spatial responses of plant C/N to different environmental factors (Yang and Wang 2011). However, there is still insufficient attention on the temporal variation in C/N, in the hope that such effort will help elucidate the mechanisms underlying plant growth/regrowth. Lucerne (*Medicago sativa* L) has long been globally utilised. It can be cut 3-4 times annually and lasts for many years. The regrowth process in lucerne is of fundamental importance for the continuous utilisation of the forage and the sustainability of lucerne production. In this study, temporal variations in carbon and nitrogen content and C/N were studied in lucerne leaf, stem and root, as part of an effort to clarify the lucerne growth/regrowth mechanisms from the viewpoint of ecological stoichiometry.

Methods

The experiment was conducted in a greenhouse in 2011. Healthy lucerne seeds were sown and normal post-sowing management was applied. Three weeks after seedling emergence, plant samples were taken in three sets of sequential cuts and separated into leaf, stem and root. The total nitrogen (TN) content was measured by using the semi-micro-Kjeldahl method. The organic carbon (OC) content was measured by potassium dichromate/ sulphuric acid mixture titration method. Then the content ratio of organic carbon and total nitrogen (OC/TN) was calculated to represent ecological stoichiometry.

Results

OC content of lucerne leaf, stem and root dropped and then rose in the first cut, rose in the second cut and rose then dropped in the third cut (Fig. 1a). As lucerne grows/re-grows, more carbon is fixed and accumulated, so generally the OC content increases in all cuts. However, a high value of OC content was observed in the first measurement of the first set of cuts. The definite reason for this could not be ascertained, but quick carbon fixation and slow consumption of carbohydrates (indicating low growth rate) might result in this consequence. Similarly and oppositely, due to high growth rate of lucerne, the OC content dropped in the end of the final set of cuts. In this study, leaf OC content was the greatest in the first set and least in the second set, while root OC content was the greatest in the second and third sets (Fig. 1a). Greatest OC content in leaf in the first set also implied that more carbon was accumulated and less was allocated, suggesting the low growth rate. As lucerne grows normally and tissue lignifies more, these trends in root OC content are explainable.

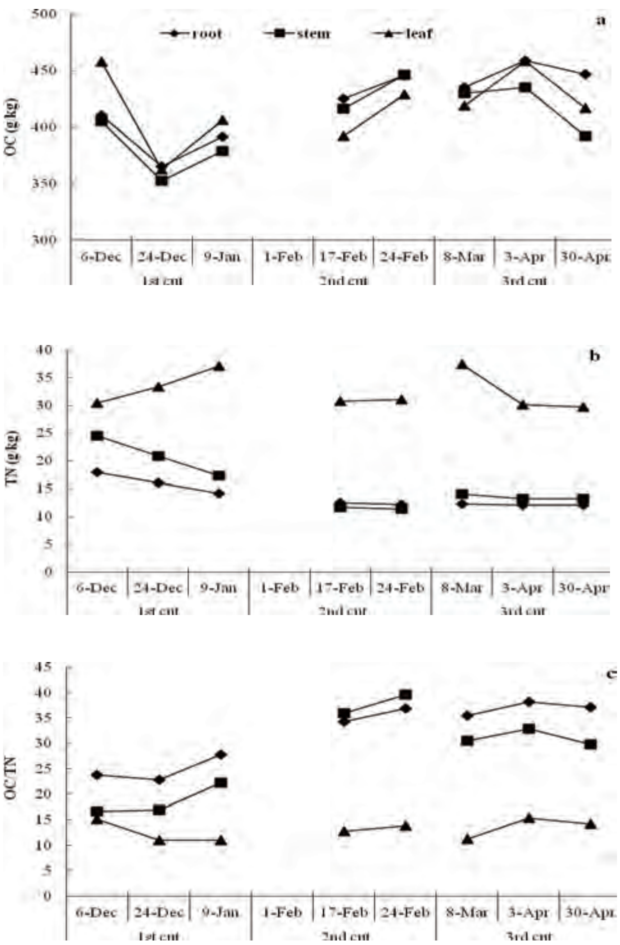

Figure 1. Temporal variation in OC (a), TN (b) content and OC/TN (c) in the leaf, stem and root of lucerne.

Table 1. Correlation of OC, TN content and OC/TN among the leaf, stem and root of lucerne. * signifies *P*<0.05.

		TN			OC/TN		
		root	stem	leaf	root	stem	leaf
OC	root	-0.494*	-	-	0.769*	-	-
	stem	-	-0.550*	-	-	0.750*	-
	leaf	-	-	-0.280	-	-	0.715*
TN	root	1	-	-	-0.913*	-	-
	stem	-	1	-	-	-0.939*	-
	leaf	-	-	1	-	-	-0.861*

Leaf TN content tended to rise in the first two sets of cuts and dropped in the third set, and TN content of stem and root tended to drop in all cuts (Fig.e 1b). Generally, the decrease in TN content is foreseeable in lucerne during the growing process because the plant is growing quicker and bigger, and nitrogen supply (uptake) can not keep up with its consumption. However, in the leaf, an opposite situation was observed due to more nitrogen supply. Dramatically, the high growth rate of lucerne leaf in the third cut might require more nitrogen to be allocated and this would lead to nitrogen dilution (Townsend 2007). So TN content dropped in the leaf of the third cut. Additionally, with the growth/regrowth of lucerne, tissue lignification turns more obvious in the stem and root, and more nitrogen is preferably allocated to the leaf. So in this study, leaf TN content was the greatest and root TN content was the least in the first and third cut while stem TN content was the least in the second cut.

The OC/TN changed oppositely compared to TN content (Fig. 1c). It dropped in the first cut, rose in the second cut and rose then dropped in the third cut for the leaf while for the stem and root, tended to drop then rose in the first cut, rose in the second cut and rose then dropped in the third cut. Leaf OC/TN was the least in all cuts and root OC/TN was the greatest in the first and third cut while in the second cut stem OC/TN was the greatest. The results suggested that the leaf and stem have the greater nitrogen use efficiency than the root. This may be because the aboveground part of lucerne plays a more active and vital role during the growing process, and the root is more like the source and channel for nitrogen.

A negative correlation was observed between OC content and TN content in lucerne (*P*<0.05) though without significance in the leaf (Table 1), confirming that carbon fixation and nitrogen uptake are closely linked during the growing process of lucerne. In addition, OC/TN was positively correlated with OC content and negatively correlated with TN content (*P*<0.05).

Conclusion

In conclusion, as lucerne grows/re-grows, more carbon is fixed in the leaf and more nitrogen is extracted from the soil and absorbed through the root. However, OC and TN content vary at different growing stages. OC/TN is the consequence of lucerne growth/regrowth, suggesting some coupling and trade-off between carbon gain and nitrogen utilisation at different growing stages.

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References

Sterner RW, Elser JJ (2002). Ecological Stoichiometry: The Biology of Elements from Molecules to the Biosphere. (Princeton University Press: Princeton)

Townsend AR, Cleveland CC, Asner GP, Bustamante MMC (2007). Controls over foliar N: P ratios in tropical forests. *Ecology* **88**, 107-118.

Yang H, Wang D (2011). Advances in the study on ecological stoichiometry in grass-environment system and its response to environmental factors. *Acta Prataculturae Sinica* **20**, 244-252.