Changes in the content and allocation of carbon and nitrogen during forage regrowth

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Keywords: Carbohydrate, coupling, herbaceous plant, nitrogen, cutting and grazing.

Introduction

Regrowth after cutting or grazing perennial grasslands sustains the production potential of forage and the persistence of grassland species. The changes in nature, content and allocation of compounds within plant parts are fundamentally correlated to the forage regrowth process (Lambers *et al.* 2008). These compounds are sourced from reserves and new assimilates. Carbohydrates and proteins stored mainly in the stem base and the root play an important role at the early stages of regrowth (Meuriot *et al.* 2004). The newly assimilated compounds include carbon from photosynthesis for the residual leaf and stem, and nitrogen absorbed by the roots from which amino acids and proteins will be produced (Dhont *et al.* 2003). Assimilates change as the forage regrows, playing a key role in the later stages. This mini-review summarises the changes in the content and allocation of carbon and nitrogen after cutting or grazing.

Changes in carbon and nitrogen content after cutting or grazing

Carbon content drops sharply after cutting or grazing and then increases. Respiration is enhanced in forage plants as an initial response to the 'cutting' or 'grazing' stimulus, resulting in a decline in the level of water soluble carbohydrates (WSCs) in the sward compared with before cutting or grazing. Then, part of the carbon reserve is activated and metabolised, leading to a decrease in carbon content and an increase in WSC content. These WSCs would be translocated into the residual leaf and stem, helping regrowth. As forage regrowth proceeds, the leaf and stem are re-built and their physiological functions are recovered, contributing to a prolonged increase in the content of WSCs and carbon in the plants that make up the sward. Carbon is a source for forage regrowth and some of the plant carbon may be re-stored into the stem base and the root.

Similarly, the nitrogen content of perennial grasses decreases gradually after cutting or grazing and then increases. The nitrogen stored in the root and stem base is translocated into the residual leaf and stem to support re-growth of leaf and stem, but nitrogen uptake from soils may not compensate effectively, leading to a reduction in plant nitrogen content. However, plant N increases as forage regrows. During regrowth, nitrogen uptake by roots is enhanced, responding to more carbon allocation to roots. Finally, nitrogen assimilation exceeds exhaustion, leading to an increase in plant (sward) nitrogen content.

Changes in carbon and nitrogen allocation during forage regrowth

The allocation of carbon and nitrogen within the sward (or plant, tiller) changes after cutting or grazing. Reserve compounds are largely translocated into residual leaves and stems after cutting or grazing (Avice *et al.* 2003) and newly assimilated carbon and nitrogen are largely allocated into the shoots but not roots (Erice *et al.* 2011). Both mechanisms help the emergence of new buds, leaves and stems and the recovery of photosynthesis. As the above-ground part of forage is reconstructed, photosynthesis is enhanced, more carbon is assimilated and an increasing proportion is translocated into roots. Some of the carbon translocated into roots is stored and the remainder helps increase nitrogen uptake and storage.

The mobilisation of carbon and nitrogen during forage regrowth is closely connected (Yang and Luo 2011). The carbon allocated into roots is less at the early stages of regrowth, resulting in retarded respiration of roots and reduced nitrogen uptake. The initial reduction in nitrogen uptake delays or slows the reconstruction of assimilating organs, restricting photosynthesis. As the forage re-grows, more carbon is assimilated, more nitrogen is absorbed following the exhaustion of carbon through root respiration, and this nitrogen uptake promotes carbon assimilation.

Concluding remarks

The changes in carbon and nitrogen content and allocation might be regulated through some signalling cascade during regrowth (Fig. 1). The actual signals involved in the processes and how they operate is not yet clear. Evidence from the literature contains some clues that calcium, antioxidant enzymes, organic acids etc. might play important roles in the regrowth process (Papatheodorou and Stamou 2004), but their role is not properly defined or understood. Considering the close link between carbon and nitrogen during regrowth, their ecological stoichiometry could be explored to further understand the mechanisms underlying forage regrowth (Fig. 1).

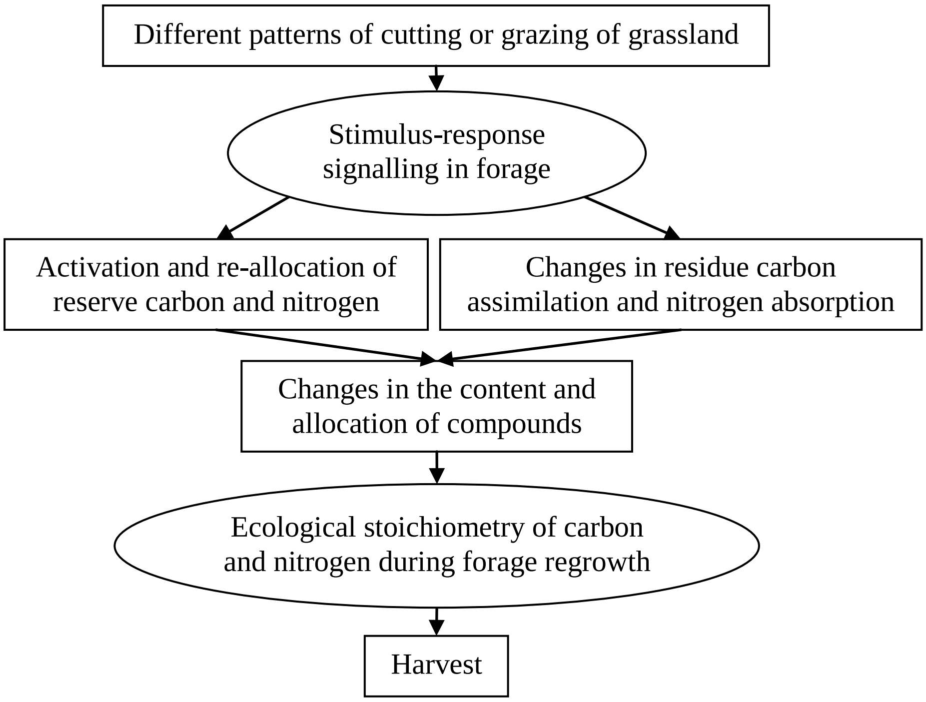

Figure 1. Simplified model for the mechanism of forage regrowth.

Acknowledgements

This study is jointly supported by the grants from the National Natural Science Foundation of China (31172248), the Special Programme of Key Research in Science and Technology of Gansu Province (1203FKDA035) and the Research Programme for the Returned Overseas Chinese Scholar from the Ministry of Human Resources and Social Security of China (to HY).

References

Avice JC, Dily FL, Goulas E, Noquet C, Meuriot F, Volenec J, Cunningham S, Sors T, Dhont C, Castonguay Y, Nadeau P, Bélanger G, Chalifour F-P, Ourry A (2003). Vegetative storage proteins in overwintering storage organs of forage legumes: roles and regulation. *Canadian Journal of Botany* **81**, 1198-1212.

Dhont C, Castonguay Y, Bélanger G, Nadeau P, Chalifour FP (2003). Alfalfa root nitrogen reserves and regrowth potential in response to fall harvests. *Crop Science* **43**, 181-194.

Erice G, Sanz-Sáez A, Aranjuelo I, Irigoyen JJ, Aguirreolea J, Avice J-C, Sánchez-Díaz M (2011). Photosynthesis, N_2 fixation and taproot reserves during the cutting regrowth cycle of alfalfa under elevated CO_2 and temperature. *Journal of Plant Physiology* **168**, 2007-2014.

Lambers H, Chapin FS, Pons TL (2008). 'Plant Physiological Ecology', 2nd edition. (Springer: New York)

Meuriot F, Avice J-C, Simon J-C, Laine P, Decau M-L, Ourry A (2004). Influence of initial organic N reserves and residual leaf area on growth, N uptake, N partitioning and N storage in alfalfa (*Medicago sativa*) during post-cutting regrowth. *Annals of Botany* **94**, 311-321.

Papatheodorou EM, Stamou GP (2004). Nutrient attributes of tissues in relation to grazing in an evergreen sclerophyllous shrub (*Quercus coccifera* L.) dominating vegetation in Mediterranean-type ecosystems. *Journal of Arid Environments* **59**, 217-227.

Yang Y, Luo Y (2011). Carbon : nitrogen stoichiometry in forest ecosystems during stand development. *Global Ecology and Biogeography* **20**, 354-361.