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LONG-TERM EFFECTS OF CO_2 ENRICHMENT AND TEMPERATURE INCREASE ON FORAGE QUALITY IN A TEMPERATE GRASS

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ABSTRACT

Perennial ryegrass swards were grown during two years at two N fertilizer supplies in elevated (700 ppm) or ambient atmospheric CO_2 concentration at outdoor temperature and at + 3°C in elevated CO_2. Elevated CO_2 and temperature increase had only minor impacts on the digestibility and on the fiber composition of the cut material. On average, the water soluble carbohydrate concentration of the leaf laminae was doubled in elevated CO_2, whereas a 3°C temperature increase reduced this concentration by 25 %.

KEYWORDS

Carbohydrate, climate change, CO_2, digestibility, fructan, lignin, ryegrass, temperature.

INTRODUCTION

The aim of this study was to determine whether the current increase in the atmospheric CO_2 concentration and the predicted increase in the average air temperature might affect the quality for ruminants and the digestibility of a C_3 grass forage. For C_3 plants, higher CO_2 levels favour the photosynthetic carbon reduction over the photorespiratory cycle, often causing an increase in the concentration of non-structural carbohydrates and a decrease in the nitrogen concentration in the leaf (Soussana et al., 1996). In their review, Field et al. (1992) stated that a high carbohydrate status and a high C:N ratio often promoted the synthesis of secondary metabolites such as lignin. Moreover, an increase in air temperature is likely to promote lignification (Van Soest et al., 1978) and, hence, to reduce digestibility. In the present study, the effects of elevated CO_2 (700 ppm) and of a 3°C increase in air temperature on the chemical composition and on the *in-situ* digestibility of perennial ryegrass were studied at two N-fertilizer supply levels.

MATERIALS AND METHODS

Perennial ryegrass swards (*Lolium perenne* L., cv Préférence) were grown in 0.5 m^2 (45 cm depth) containers, filled with a loamy soil, at two N fertilizer supplies: 160 (N-) and 530 (N+) kg N ha^{-1} yr^{-1}. These established swards were exposed from March 1993 to July 1995 in highly ventilated plastic tunnels to elevated (700 ppm) or ambient atmospheric CO_2 concentration at outdoor temperature and to a 3°C increase in air temperature in elevated CO_2. All swards were cut simultaneously at a 4 cm height in May, June, July, September and October and were kept in a vegetative stage by the spring cuts (Soussana et al., 1996).

In May and June 1994, before cutting and around 12:00 h solar time, mature tillers (sampled from five replicates containers) were cut at the ground level and were separated into leaf lamina, pseudo-stem and dead material. The leaf lamina samples were freeze dried, extracted first in alcohol:water (40/60) v/v mixture and then in distilled water. After purification, water soluble carbohydrates (WSC) were quantified by high pressure liquid chromatography, using a HPX-87 P column (Biorad, France) and a refractometer.

In May and June 1994 and 1995, at cutting date, the harvested material was dried at 70°C during 24 h and ground to pass through a 1 mm grid. The dry matter was fractionated into neutral (NDF) and acid (ADF) detergent fibers, according to Goering and Van Soest (1970) except that cetyl trimethyl ammonium bromide was omitted for ADF preparation. Lignin was determined on ADF according to Jarrige (1961). Hemicellulose and cellulose were determined on the filtrates from ADF and lignin residues, the hydrolysed polymers being analysed as reducing sugars (Besle et al., 1981). Dry-matter degradation was determined in triplicate by the nylon bag method (50µm pore size, Demarquilly and Chenost, 1969). The bags were placed in a fistulated cow fed with cocksfoot hay, incubated for 48h, frozen, thawed, washed and dried (60°C). *In situ* dry matter (ISDMD) and *in situ* NDF disappearances were corrected for the measured physical losses of fine particles through the bags.

RESULTS AND DISCUSSION

A very large increase in the fructan concentration (+357 %) was observed in elevated CO_2, whereas the corresponding increase in the hexose and sucrose concentration was moderate (+33 %) and occured only at N+ (Tab. 1). A 3°C temperature increase in elevated CO_2 reduced significantly the WSC and the fructan concentrations (Table 1) and increased, at N-, the hexose and sucrose concentrations (Table 1).

The CO_2 and temperature increases resulted in a positive trend for the NDF content of the dry-matter and in a lower cellulose content of the NDF (Table 1). The content of lignin in the fiber was reduced concomitantly to that of cellulose in elevated CO_2 but was increased by a supplemental 3°C, in agreement with van Soest et al. (1978) (Table 1). The ISDMD was reduced by the temperature increase, especially at the low N supply. The decrease observed is consistent with that of 0.64 percent per °C reported by Wilson and Wong (1982). This decrease is mostly due to a lower nitrogen content in DM (Soussana et al., 1996) and to a lower NDF degradability, which is linked to the greater lignin content (Table 1).

In agreement with the report by Akin et al. (1995), with a C_3 grass of a high forage quality for ruminants, these results show that elevated CO_2 and temperature increase had only minor impacts on the digestibility and on the fiber composition of the cut material. Nevertheless, the increase in the WSC concentration of the leaf laminae in elevated CO_2 could lead to a faster digestion in the rumen. Also, the 25-33% decline in the Kjeldahl-N concentration of the harvested material, which was previously reported by Soussana et al. (1996), is likely to reduce the nitrogen value of the grass forage and, hence, the needs for supplements. An increase of the air temperature, due to global warming, might mitigate these changes in the soluble carbohydrate and protein contents of temperate grass forages.

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Table 1
Chemical composition and digestibility at cutting date of perennial ryegrass grown in ambient (35) or elevated CO_2 (700) at outdoor temperature and in elevated CO_2 at +3°C (700+). The results are the mean of the May and June cuts.

		N-			N+			
		350	**700**	**700+**	**350**	**700**	**700+**	**SEM**[z]
WSC	g/kg^{-1} DM	120[a]	239[c]	168[b]	67[a]	154[c]	126[b]	15
Simple sugars	g/kg^{-1} DM	71[a]	61[a]	82[b]	61[a]	81[b]	82[b]	5
Fructans	g/kg^{-1} DM	49[a]	178[c]	86[b]	6[a]	73[c]	44[b]	15
NDF	gkg^{-1} DM	509[a]	518[a]	531[a]	465[a]	504[a]	517[a]	19
Hemicellulose	g/kg^{-1} NDF	181[a]	204[a]	194[a]	196[a]	189[a]	195[a]	11
Cellulose	g/kg^{-1} NDF	463[b]	429[a]	423[a]	444[a]	439[a]	433[a]	7
Lignin	g/kg^{-1} NDF	81[b]	61[a]	85[b]	73[ab]	63[a]	83[b]	6
DM degradability	%	88[b]	89[b]	86[a]	88[b]	85[ab]	84[a]	1.1
NDF degradability	%	77[b]	78[b]	73[a]	75[b]	70[ab]	68[a]	1.4

[z] Standard error of the mean
[a,b] Values of the same N supply treatment with different superscripts are different, $P<0.05$