Effect of increased autumn temperature and CO_2 concentration on frost hardening and winter survival in *Lolium perenne*

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Introduction Before 2100, the average autumn temperature in Norway is expected to increase by 1.4 to 5.9 °C (RegClim, 2005). At the same time, the CO_2 concentration will increase. The aim of the present study was to investigate how a temperature increase during autumn will affect frost hardening, winter survival and spring growth of perennial ryegrass (*Lolium perenne* L.) on a coastal location in Norway, at the present and a future CO_2 level.

Materials and methods The experiment was carried out in open-top chambers at Særheim (58.76°N, 5.65°E, 90 m a s l, 8 km from the coast). Two cultivars of perennial ryegrass (Riikka, Gunne), were established in June 2005 in 10 l polyethylene bags filled with a fertilized sand-peat mixture, placed side-by side in the chamber. There were 10 plants per bag and 20 bags per m^2. The ground area of the chambers were 3.4 × 2.5 m^2 and they were surrounded by 1.9 m high transparent plastic foil mounted on wooden frames, which reduced the incoming light by 15%. In eight of the chambers, heaters were included in the air flow in order to increase the air temperature by about 2°C from Aug. to Dec. Eight chambers were supplied with CO_2 gas to increase the CO_2 concentration by about 170 μmol mol^{-1} from June to Dec. There were 4 treatments, each replicated 4 times: Ambient CO_2/ambient temperature, ambient CO_2/high temperatur, high CO_2/ambient temperature and high CO_2/high temperature. Tillers were counted and tested for frost tolerance (LT_{50}; temperature required to kill 50% of the population) (Larsen, 1978). Spring growth was evaluated by harvesting the total above-ground biomass on 6 June. Data were subjected to ANOVA.

Results Increased CO_2 concentration had no effect on the frost tolerance (Table 1). Increased autumn temperature, on the other hand reduced the frost tolerance. This effect was evident on 15 Dec. when there was 1℃ difference in LT50 between the treatments. However, the difference levelled out as the winter proceeded. Riikka was more frost tolerant than Gunne. There were no treatment differences in tiller density or spring growth (not shown), except for a 35% lower ($P<0.05$) density in Riikka. The average (monthly minimum) temperature for each month from Aug. 2005 to May 2006 in order were 13.5 (7.0), 12.6 (5.5), 5.8 (0.9), 3.6 (-2.7), 1.5 (-5.5), 1.5 (-3.4), 1.5 (-4.3), -0.4 (-10.8), 4.7 (-1.0), and 10.1 (3.2) ℃. The soil was bare, except for a few days of snow cover in Dec. and 3 weeks in Feb/March (maximum depth 10 cm). Total precipitation was 732 mm from Aug. to Dec., and 400 mm from Jan. to May. There was no interaction between cultivar, CO_2 and temperature for any parameter.

Table 1 *Frost tolerance (LT50, ℃) as affected by temperature, CO_2 concentration, and cultivar.*

	Temperature		CO_2		Cultivar			Significanceb		
	Ambient	High	Ambient	High	Riikka	Gunne	SEMa	T	CO	CV
Nov.	-10.0	-10.0	-9.9	-10.1	-11.2	-8.8	0.40	ns	ns	***
Dec.	-12.7	-11.7	-11.9	-12.5	-13.2	-11.2	0.30	*	ns	***
March	-10.5	-10.7	-10.4	-10.7	-10.8	-10.3	0.35	ns	ns	ns

[a]SEM = standard error of the mean; [b]Statistical significance; ns, non-significant; *, $P<0.05$; ***, $P<0.001$; T = effect of temperature; CO = effect of CO_2; CV = effect of cultivar. There were no interactions ($P>0.10$) between T, CO and CV.

Conclusions The predicted increase in CO_2 will have a limited effect on the frost hardening in this coastal environment. A temperature increase of 2 °C in the autumn will delay hardening and reduce the frost tolerance to some extent. However, the best available cultivars will in most cases be frost hardy enough even with this small reduction.

References

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