DROUGHT TOLERANCE OF PERENNIAL RYEGRASS (*LOLIUM PERENNE* L.) AND THE ROLE OF *EPICHLOË* ENDOPHYTE

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Abstract

Perennial ryegrass is the most important grass species in New Zealand. Due to climate change, drought will become more severe and frequent in New Zealand, which makes it increasingly important to improve drought tolerance of perennial ryegrass. There are many ryegrass cultivars in the seed market; however, very limited information is available about drought tolerance of these cultivars. Therefore, the first aim of this thesis was to compare drought tolerance of several market-leading perennial or long-rotation ryegrass cultivars in order to provide cultivar information for pastoral industry. *Epichloë festucae* var. *lolii* fungal endophyte naturally colonises perennial ryegrass. Reported effects of endophyte on drought tolerance of the host perennial ryegrass are multifarious. Therefore, the second aim of this thesis was to investigate effects of endophyte on drought tolerance of perennial ryegrass comprehensively.

Two main experiments were conducted in this PhD project. In the first experiment, endophyte-free (E–) and endophyte-infected (E+) cloned plants of seven perennial or long-rotation ryegrass cultivars (Grasslands Commando, Ceres One50, Banquet II, Alto, Bealey, Trojan and Avalon), an un-released elite perennial ryegrass line (URL) and one Mediterranean tall fescue cultivar (Grasslands Flecha) were subjected to a cycle of drought and rehydration from December 2012 to May 2013 while other clones of the same plants were irrigated. In the second experiment, two perennial ryegrass cultivars One50 and Commando infected with and without the AR37 endophyte were subjected to a glasshouse experiment. Eight genotypes of each cultivar with and without endophyte infection were either under irrigation or withheld irrigation for two weeks and then rehydrated for one month. A series of plant morphological and physiological responses were measured in each experiment.

In the rainout shelter experiment, it was found that Flecha tall fescue was more tolerant to drought than ryegrass cultivars, but this was attributed to its small plant size induced by the partial summer dormancy. Introducing germplasm from Mediterranean areas would be an option to improve drought tolerance of perennial ryegrass in New Zealand. Among evaluated ryegrass cultivars, Banquet II was relatively more drought tolerant than other cultivars, which was also mainly due to its small plant size. In the glasshouse experiment, it was found that Spanish

germplasm based One50 was more drought tolerant than ‘Mangere’ ecotype based Commando, suggesting that Spanish germplasm has conferred enhanced drought tolerance to perennial ryegrass in New Zealand.

Under both irrigated and non-irrigated conditions, endophyte infection reduced the herbage yield, decreased the relative water content, osmotic potential and stomatal conductance (as indicated by carbon isotope discrimination) and increased the proline concentration of the host compared to E– plants. Also, a majority of these effects were more pronounced in the URL (infected with AR37) and One50 (infected with AR1). It was concluded that E+ plants are at a disadvantage compared to E− plants when insect pressure is artificially controlled, no matter whether the water availability is high or low.

KEY WORDS: *Epichloë coenophiala*, *Epichloë festucae* var. *lolii*, *Festuca arundinacea*, gas exchange, nitrogen uptake, pasture production, plant water relations, water deficit.

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Glossary of Abbreviations

Abbreviation	Full name/meaning	Unit
$\Delta^{13}C$	Carbon isotope discrimination	‰
ABA	Abscisic acid	
ABB	Africa black beetle	
AMF	Arbuscular mycorrhizal fungi	
APX	Ascorbate peroxidase	
ART	Aligned rank transformation	
ASW	Argentine stem weevil	
ATP	Adenosine triphosphate	
CAT	Catalase	
CF	Chlorophyll fluorescence	
DM	Dry matter	g/plant
E−	Endophyte-free	
E+	Endophyte-infected	
EC	Electric conductivity	
EL	Electrolyte leakage	%
FC	Field capacity	
FW	Fresh weight	g
GAPDH	Glyceraldehyde-3-P-dehydrogenase	
GLM	General linear model	
GPX	Glutathione peroxidase	
G_s	Stomatal conductance	mol H_2O m^{-2} s^{-1}
I−	Non-irrigation	
I+	Irrigation	
LER	Leaf elongation rate	mm/tiller/day
LSR	Leaf senescence rate	mm/tiller/day
LWP	Leaf water potential	bars
MDA	Malondialdehye	nmol/g leaf DM
NADP	Nicotinamide adenine dinucleotide phosphate	
NADPH	Nicotinamide adenine dinucleotide phosphate hydrogen	
NIWA	National Institute of Water and Atmospheric Research	
NRL	New root length	cm
OA	Osmotic adjustment	bars
OM	Organic matter	g/plant
OP	Osmotic potential	bars
P_n	Net photosynthesis rate	µmol CO_2 m^{-2} s^{-1}
POD	Peroxidase	
PWP	Permanent wilting point	
RC	Ring colonization	

RD	Reproductive development	
RLDM	Regrowth leaf dry matter	g/plant
ROS	Reactive oxygen species	
RuBisCO	Ribulose-1,5-bisphosphate carboxylase/oxygenase	
RWC	Relative water content	%
RSR	Root: shoot ratio	
SBP	Sedoheptulose-1,7-bisphophatase	
SOD	Superoxide dismutase	
SWC	Soil water content	%
N%	Total nitrogen concentration	%
TP	Turgor pressure	bars
T_r	Transpiration rate	mmol H_2O m^{-2} s^{-1}
TSR	Tiller survival rate	
TTN	Total tiller number	
TW	Turgid weight	g
WSC	Water soluble carbohydrates	
WUE	Water use efficiency	
$\delta^{13}C$	Carbon isotope composition	‰
$\delta^{15}N$	Nitrogen isotope composition	‰

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