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**DROUGHT TOLERANCE OF PERENNIAL RYEGRASS (*LOLIUM  
PERENNE* L.) AND THE ROLE OF *EPICHLÖE* 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<sup>-</sup> 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<sup>+</sup> plants are at a disadvantage compared to E<sup>-</sup> 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   |
|-----------------------|--|--|
| $\Delta^{13}\text{C}$ | Carbon isotope discrimination                        | ‰  |
| ABA                   | Absciscic 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                                 | $\text{mol H}_2\text{O m}^{-2} \text{ s}^{-1}$     |
| 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                   | Malondialdehyde                                      | 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                              | $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ |
| 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<br>carboxylase/oxygenase |   |
| RWC               | Relative water content                             | %   |
| RSR               | Root: shoot ratio                                  |   |
| SBP               | Sedoheptulose-1,7-bisphosphatase                   |   |
| SOD               | Superoxide dismutase                               |   |
| SWC               | Soil water content                                 | %   |
| N%                | Total nitrogen concentration                       | %   |
| TP                | Turgor pressure                                    | bars  |
| T <sub>r</sub>    | Transpiration rate                                 | mmol H <sub>2</sub> O m <sup>-2</sup> s <sup>-1</sup> |
| TSR               | Tiller survival rate                               |   |
| TTN               | Total tiller number                                |   |
| TW                | Turgid weight                                      | g   |
| WSC               | Water soluble carbohydrates                        |   |
| WUE               | Water use efficiency                               |   |
| δ <sup>13</sup> C | Carbon isotope composition                         | ‰   |
| δ <sup>15</sup> N | Nitrogen isotope composition                       | ‰   |

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