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**GROWTH OF PASTURE SPECIES IN THE SHADE
IN RELATION TO ALDER SILVO-PASTORAL
SYSTEMS**

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ABSTRACT

An increased understanding of the competitive interactions between tree species and understorey pastures is required for the development of deciduous tree based silvo-pastoral systems. In particular, the shade tolerance of pasture species likely to be used under trees in New Zealand needs to be determined. This thesis examines the effects of light intensity and quality on the growth of pasture species in a series of glasshouse experiments, and under the shade of alder trees pruned to different heights.

The shoot dry weight per plant of all grass and legume species examined showed a linear increase ($P < 0.0001$) with % ambient photosynthetically active radiation (PAR). Highest shoot dry weight was at 73% and lowest was at 14% PAR (heavy shade). Shade also affected the tillering ability of pasture species. Under heavy shade, cocksfoot (*Dactylis glomerata* L.) produced more tillers per plant than the other grass species examined. Perennial ryegrass (*Lolium perenne* L.) had the lowest tillering in heavy shade. Under medium shade (43% ambient PAR), tiller number per plant for browntop (*Agrostis capillaris* L.) and Poa trivialis (*Poa trivialis* L.) was higher than other species. Lotus (*Lotus uliginosus* L.) produced a higher ($P < 0.0001$) number of branches under heavy shade than white clover (*Trifolium repens* L.) and subterranean clover (*Trifolium subterraneum* L.).

Shade affected perennial ryegrass more than cocksfoot selections, especially at the lowest PAR level both in the glasshouse and the field experiment. For example, tillers per plant under tree shade, and also at the low PAR level in the glasshouse for perennial ryegrass were 18 compared with 28-29 ($P < 0.0001$) for Wana cocksfoot and 24-27 for PG 74 cocksfoot. Leaf area per plant for perennial ryegrass was also significantly ($P < 0.0001$) lower than for Wana cocksfoot. Cocksfoot selections were more tolerant of heavy shade than perennial ryegrass, and Wana was the most tolerant of the cocksfoot selections of heavy shade.

There were no effects of R:FR ratio ($P > 0.05$) on the shoot dry weight production of the pasture species examined. Similarly, the interaction between PAR \times R:FR and species

was not significant ($P>0.05$) for most morphological characteristics when plants were not defoliated. Perennial ryegrass, Wana cocksfoot and Yorkshire fog (*Holcus lanatus* L.) at low PAR had similar yields, that higher than white clover and lotus, which were similar. However, when plants were defoliated weekly or three-weekly, Wana cocksfoot out produced Nui perennial ryegrass at low PAR/R:FR due to its ability to maintain higher leaf area and higher leaf dry weight, higher SLA, and more tillers per plant.

Herbage mass of swards in heavy and medium shade created by pruning alder trees was about 50% and 70%, respectively, of that of light shade ($P<0.0001$). Herbage mass was highest for cocksfoot either with lotus or white clover ($P<0.0001$), whereas values for perennial ryegrass and Yorkshire fog were lower and similar. Shade affected perennial ryegrass more than cocksfoot and Yorkshire fog, especially at the lowest PAR level. Cocksfoot in mixture with either white clover or lotus had the highest leaf expansion per tiller, which was in the order cocksfoot > Yorkshire fog > perennial ryegrass. There was no significant difference ($P>0.05$) between the pasture species in the total number of sheep grazing observations in 2 hours, but more sheep grazed in light shade than in heavy shade ($P<0.05$).

The research highlighted the importance of measuring shade tolerance of pasture species in terms of attributes that determined growth and persistence. As perennial pasture species are regularly defoliated they must be able to vegetatively reproduce in the shade as well as be productive. Shade tolerance of the pasture species examined varied greatly, but their relative shade tolerance was also sensitive to the level of shade. Although, cocksfoot was the most shade tolerant species in heavy shade (PAR level $<200 \mu\text{moles photons m}^{-2} \text{ s}^{-1}$) it was similar to other species in medium shade (PAR level $\geq 400 \mu\text{moles photons m}^{-2} \text{ s}^{-1}$ or more).

Light intensity was more important for growth and vegetative reproduction than light quality for pasture species under shade. Likewise, pruning trees was more important for pasture production under tree shade. The morphological attributes related to shade tolerance of New Zealand hill country pastoral plants were identified in this thesis as tiller number per plant, leaf area, specific leaf area (SLA), and leaf appearance interval.

For alder silvo-pastoral systems with high tree density and heavy shade (PAR level $<200 \mu\text{moles photons m}^{-2} \text{ s}^{-1}$) cocksfoot in combination with either lotus or white clover was the most productive pasture, while perennial ryegrass, or browntop, with white clover was as productive as cocksfoot if shade was maintained at a PAR level $>200 \mu\text{moles photons m}^{-2} \text{ s}^{-1}$). Additionally, cocksfoot and lotus are both tolerant of the low to medium soil fertility and seasonal dry periods likely to be encountered on the hill country where deciduous trees are also used to control soil erosion.

Shade had a marked effect on tillering as well as on shoot dry weight, and is the most significant factor determining the understorey pasture production. However, the decrease in pasture production due to shading can be managed by appropriate pruning practices and choice of appropriate pasture species.

GLOSSARY AND ABBREVIATIONS OF TERMS USED

Agroforestry: it refers to silvo-pastoral systems oriented to timber production or soil erosion control. Agroforestry in New Zealand is often used synonymously with “farm forestry” i.e. farmers managing forest plantation on the farmland. Here, agroforestry is taken as an intensive land management practice using trees, pastures, and livestock on the same area of land at the same time.

AGR: absolute growth rate.

Agrosilviculture: a combination of crops plus trees.

Agrosilvopastoral: covers crops, pasture/animal and trees.

Breast height: breast height in New Zealand is 1.4 m above ground on the uphill side of the tree. Many other countries including Australia, use 1.3 m as breast height.

⁰C: degree Celsius.

C: carbon.

C₃: photosynthetic pathway of carbon assimilation for most of the temperate pasture species.

C₄: photosynthetic pathway of carbon assimilation for most of the tropical pasture species.

Canopy: the part of a tree consisting of branches and foliage. “Canopy closure” is the stand age when the branches at neighbouring trees touch, or nearly so, thereby restricting light to the forest floor.

CP: crude protein.

Cultivar name: all species and cultivars are fully named in the materials and methods section of each chapter. Elsewhere they are presented in an abbreviated form e.g. 'Grasslands Wana' has been referred to as Wana.

DBH: tree diameter at breast height.

Deciduous tree: broad-leaved hardwood tree that sheds its leaves during autumn/winter and develops new leaves the following spring. Some deciduous trees like alder can also fix atmospheric nitrogen.

Defoliation: practice of clipping or removing aerial plant parts. Here, defoliation means cutting pasture plants at a specific height at specific intervals.

GLM: general linear model of SAS.

HH: herbage harvested. The mass of herbage per unit area removed by mechanical means, usually expressed as g/m^2 .

Hill country: all the land with slopes between 12 and 28⁰, but low relief; typically 100 to 300m difference in elevation. Valley bottoms are usually narrow.

HM: herbage mass. The total dry weight of herbage per unit area of land, usually above ground level and at a defined reference level. Commonly expressed as g/m^2 .

Intercepted PAR: is the difference between global PAR above a canopy and PAR transmitted through a canopy.

J: joule, unit of measurement.

K: potassium.

kg: kilogram, 1000gram.

LAI: leaf area index, leaf area per unit ground area.

LAR: leaf area ratio, ratio of leaf area to whole plant dry weight.

LPC: light compensation point for photosynthesis.

Lopping: cutting one or more branches off a woody plant; synonym to pruning.

nm: nanometer.

NZMF: New Zealand Ministry of Forestry.

PB: polythene bag used as a pot to grow pasture species in glasshouse conditions.

PGU: plant growth unit.

Shelterbelt: a long narrow strip of trees and/or shrubs intended to reduce wind flow, often for agricultural gain.

Silviculture: the procedure used in growing trees, especially pruning and thinning.

Silvo-pastoral system: which includes trees plus pasture/animals. Basically pasture production is emphasised under tree shade. Generally the term agroforestry also describes silvo-pastoral systems.

Stocking rate: the number of live trees per hectare, also known as “tree density”.

TDR: time domain reflectometry.

Tissue turnover: in a given period the net change in the weight of living shoot material of a species brought about by the formation of new tissue and the gross decrease caused either by senescence and decomposition of older tissue, or by herbage intake is commonly known as tissue turnover. It is commonly expressed in $\text{g/m}^2/\text{day}$.

Thinning: the removal of trees within a stand at some time before clear felling. If trees are left lying in the forest, it is “waste thinning”. If trees are extracted, it is “production thinning”.

Transmitted PAR: when shade is created with shade cloth, transmitted PAR is measured under the shade cloth. In the case of trees, transmitted PAR is measured under the canopy.

Abbreviations related to experimental treatments

ANOVA: analysis of variance.

CL: cocksfoot with lotus.

cm²: square centimetre.

cv: cultivar.

CVA: canonical variate analysis.

CV: canonical variate.

CW: cocksfoot with white clover.

d.f.: degrees of freedom.

DM: dry matter.

Fig: figure.

g: gram.

GP: white clover growing points.

ha: hectare.

h: hours.

H/N: high natural, here denotes high PAR with natural R:FR.

L/N: low natural, here denotes low PAR with natural R:FR.

L/R: low reduced, here denotes low PAR with reduced R:FR.

LSD: least significant difference.

m²: metre square area.

mg: milligram.

mm: millimetre.

N: nitrogen.

n: number.

na: data not available.

NA: data not taken.

NS: non-significant at P=0.05.

P: phosphorus.

P: probability.

PAR: photosynthetically active radiation. Measured in $\mu\text{moles photons m}^{-2} \text{ s}^{-1}$, 400-700nm.

R:FR: red to far red ratio. Ratio of photon irradiance between 655 and 665nm, and 725 and 735nm, respectively.

RGR: relative growth rate.

RW: perennial ryegrass with white clover.

s⁻¹: per second.

SEM: standard error of the mean.

SLA: specific leaf area, the area of leaf displayed per unit of leaf weight.

SU: site usage, expressed as tillers per leaf.

vs: versus.

W1: weekly defoliation.

W3: three- weekly defoliation.

YW: Yorkshire fog with white clover.

α : statistical significance.

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