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ENVIRONMENTAL EFFECTS OF DENSELY PLANTED WILLOW AND POPLAR IN A SILVOPASTORAL SYSTEM

A thesis presented in partial fulfilment
of the requirements for the degree of

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THIS THESIS IS DEDICATED TO MY PARENTS WHO ALWAYS PRAYED FOR MY SUCCESS TO GAIN HIGHER QUALIFICATION

Abstract

New Zealand, having large areas of hilly landscapes, is subject to the risk of soil erosion, and summer and autumn droughts that limit pasture growth, which in turn affects the livestock-based economy. The nitrogen and phosphorus input in fertilisers coupled with livestock excreta and soil disturbance impose a serious threat to downstream water quality. The planting of trees is one option used to decrease soil erosion, increase the quantity of forage and manage runoff.

To date, research has mainly focused on wide spaced poplar trees for feed quality and their effects on understorey pasture growth. However, there is increasing interest in the use of densely planted willow and poplar for fodder purpose. The effects of young (< 5 yrs old) willow and poplar planted at close spacing on runoff, soil erosion, growth of understory pasture and nutrient losses have never been studied in New Zealand.

Three field trials (two at Crop and Research Unit, Moginie, Manawatu and one at Riverside Farm, Masterton) were conducted between October 2004 and November 2006 that incorporated comparative establishment and growth of densely planted willow and poplar and their effects on soil moisture, runoff, sediment load and nutrient losses from grazed and fertilised farmland.

It was concluded that densely planted willow and poplar (3-4 yrs) reduced total nitrogen (TN) and dissolved reactive phosphorus (DRP) by 47 % each and sediment load by 52 %. Young trees reduced surface runoff and soil moisture more as they aged. However, due to their deciduous nature willow and poplar were not effective in reducing surface runoff in winter and early spring. Sheep preferred camping under trees, especially in late spring and summer, and this led to greater deposition of dung and urine under trees than open pasture. Sheep grazing, especially in winter, significantly increased sediment and nutrient loads in runoff water. The N and P fertiliser application increased nutrient load in runoff water well above the threshold level required to initiate algal growth to create eutrophication.

Densely planted willow and poplar significantly reduced understorey pasture growth by 23 % and 9 %, respectively, in their second year at Moginie, mainly due to shade, but coupled with soil moisture deficit in summer. The pasture growth in a willow browse block was 52 % of that in open pasture as a result of shade and differences in pasture species composition. Sheep browsing reduced willow leaf area significantly. Willow and poplar survival rates were similar ($P > 0.05$) after two years of establishment (100 % vs 90.5 %, respectively). However, willow grew faster than poplar in height (1.90 vs 1.35 m), stem diameter (43.5 vs 32.6 mm), canopy diameter (69 vs 34 cm) and number of shoots (8.7 vs 2.3) at the age of two years, respectively.

The research clearly demonstrated that densely planted young willow and poplar trees can reduce runoff, sediment load and nutrient losses from farmland to freshwater, but shade and soil moisture can limit pasture growth under trees. It is recommended that willow and poplar should be planted at wide spacing on the whole farm to minimise loss of pasture. Where blocks of trees are necessary, such as willow browse blocks, sheep browsing can be used as a tool to reduce shade to improve pasture growth. Livestock access to riparian strips should be minimal to avoid livestock camping that can have deleterious effects on water quality.

Key words: willow; poplar; growth; nutrients; pasture; runoff; soil erosion; soil moisture; fertiliser; water; sheep; browsing; camping.

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Glossary and Abbreviations

ANOVA: analysis of variance.

Blanket forestry: plantation of whole farm with a single species, in New Zealand this usually refers to *Pinus radiata*.

^{o}C: centigrade.

cm^{-3}: per cubic centimetre.

cm: centimetre.

Canopy: the part of a tree consisting of branches and foliage.

DAP: diammonium phosphate.

DM: dry matter.

d.p: decimal point.

DOP: dissolved organic phosphorus.

DIP: dissolved inorganic phosphorus.

DRP: dissolved reactive phosphorus.

Densely planted: in this thesis it refers to pastureland planted with >6000 trees per hectare.

dia: diameter.

g: gram.

GLM: general linear model.

h: hour.

ha: hectare.

ISS: inorganic suspended solid.

Kg: kilogram.

L: litre.

LSD: least significant difference.

m: metre.

mg: milligram.

mm: millimetre.

N: nitrogen.

NHA: net herbage accumulation.

NH_4^+-N: ammonical-nitrogen.

NO_3^--N: nitrate-nitrogen.

OP: open pasture.

OSS: organic suspended solid.

P: phosphorus.

PAR: photosynthetically active radiation.

PP: poplar pasture....pastureland planted with poplar trees

RCB: refers to experimental design as randomised complete block

SAS: statistical analysis system.

SEM: standard error of mean.

SSP: single superphosphate.

TKN: total kjeldahl nitrogen.

TN: total nitrogen.

TP: tree pasture...pastureland planted with trees.

TP: total phosphorus.

TSS: total suspended solid.

WP: willow pasture....pastureland planted with willow trees

yr: year.

yrs: years.

Zone 3: the centre of four nuclei trees planted at a square grid.

θ**:** soil moisture content.

ω**:** soil volume at a given depth.

µg: microgram.