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**A STUDY OF THE COMBINED EFFECTS OF
IRRIGATION FREQUENCY AND PHOSPHORUS
FERTILITY ON SUMMER PASTURE PRODUCTION**

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

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ABSTRACT

During the last five years, there has been an increase in both the area of irrigated pasture in New Zealand and the intensity of this irrigation. Research has failed to keep pace with this change: the benefits of irrigation to pasture production have not been studied in a sustained manner since the 1980s. Since then a number of factors have changed including; a change in the type of irrigation system commonly employed, the productive potential of new pasture cultivars, an appreciation of the importance of relationships between water and nutrient uptakes by plants, and a heightened awareness of the environmental implication of irrigation.

It is claimed that the ability of irrigation systems such as centre pivot and long lateral systems to increase irrigation frequency affords a major advantage to pasture production. As yet, these claims are largely unsubstantiated in New Zealand. In addition, there has been no research of the mechanisms or processes that might account for this phenomenon. The study described here set out to quantify the benefits of more frequent irrigation (in the readily available water range) to ryegrass and white clover production, including the relationship with increased nutrient status, and to elucidate the mechanism(s) that might explain this response.

The responses of ryegrass and white clover to irrigation frequency (within the readily available water range) and nutrient addition, particularly phosphorus (P) were investigated with a pot experiment using Ramiha silt loam. The rate of fertiliser addition to the pots had a significant and consistent effect on a number of indicators of ryegrass and clover performance including total yield. In contrast, irrigation frequency did not significantly or consistently affect total pasture production. It was concluded that when soil, nutrients and plants roots constitute a relatively homogenous mix (i.e. the pot environment), more frequent watering is not significantly advantageous to plant growth and, therefore, all of the readily available water is equally available.

Although there was no response in pasture production to irrigation frequency in the pot experiment, it was hypothesised that irrigation frequency (in the readily available range) in the field, where P values vary with depth in the soil profile, would affect pasture production. The response of swards of ryegrass and white clover growing in Manawatu fine sandy loam to irrigation frequency and P status was measured in a field experiment during the summer of 2000/01. Three irrigation frequencies within the readily available water range (irrigation triggered at soil water deficits of 20 mm (I-20), 40 mm (I-40) or 60 mm (I-60)) were combined with two P fertility treatments (no P fertiliser added or 40 kg P ha⁻¹ applied). For comparative purposes, there were also 4 non-irrigated, non-P fertilised plots outside the main trial block. Plant production, nutrient content of plant material, soil moisture content, soil N and P contents, and nitrate-N, ammonium-N and phosphorus concentrations of soil water samples were measured. The herbage on the plots was cut and removed i.e. there was no grazing.

In the field, irrigation frequency had a significant effect on ryegrass and clover production. Irrigation of ryegrass and white clover at I-20, over the summer period resulted in the greatest pasture production and was associated with the most efficient water use (defined as k with units kg DM ha⁻¹) of the irrigated treatments, I-60 gave the smallest production and water use efficiency. Application of the recommended quantity of P fertiliser (40 kg ha⁻¹) significantly enhanced total pasture production and hence water use efficiency. Soil P and N was most concentrated in the surface soil. The results of the field trial support the hypothesis that ryegrass and white clover production is greatest when the plant is taking most of the water it requires from the surface soil where nutrients are most concentrated i.e. the frequent (I-20) irrigation case. Production is smaller when the plant is extracting large quantities of water from depth where nutrient concentrations are smaller i.e. the less frequent irrigation (I-60) case.

The effects of irrigation frequency and P fertility on root re-growth activity of ryegrass and white clover swards were evaluated using a modified refilled core method. Root growth of both species decreased with depth. Fertiliser P application significantly increased root growth of both species in two of the three sampling depths at the December and February harvests. In only one root harvest did irrigation frequency significantly affect root activity. At the April harvest, the greatest root growth in the surface soil was observed for I-60, P-0 plots. It is suggested that in addition to encouraging more moisture uptake from nutrient-rich surface soil, an additional benefit of frequent irrigation is that in soils that are consistently moist, plants need to produce fewer roots.

A simple water balance model was developed to simulate volumetric soil water contents in the three depths of the Manawatu fine sandy loam that are most closely related to the three irrigation frequencies i.e. 0-150 mm, 0-300 mm, and 0-450 mm. The model illustrates how initially the plants extract most of their water requirement from the surface soil and then as the profile dries they remove more water from lower depths. Accordingly, it highlighted differences in soil water contents between the irrigation frequencies particularly in the surface soil (0 - 150 mm).

Soil water sampling was conducted using ceramic suction cups. Estimated total nitrate-N losses until 31 July, 2001 indicated that irrigation frequency of ryegrass during the previous summer did not have a major effect on the overall nitrate-N leaching losses during the late autumn/early winter period but nitrate-N losses under clover tended to be lower under less frequent irrigation. P and ammonium-N leaching losses were negligible.

Using the understanding developed in the pot and field trials, a model was constructed to predict ryegrass and clover production on Manawatu fine sandy loam under the

different irrigation frequency and P fertility regimes. The model relates pasture production (G) to evaporation from a series of soil water deficit ranges (E_i) according to $G = k_1E_1 + k_2E_2 + \dots + k_nE_n$ (where k_iE_i is the pasture production when soil water is in the i^{th} soil water deficit range, and k_i is the water use efficiency when soil water is in the i^{th} soil moisture deficit). The k_i values were derived using the production data from the field trial. The model was used to simulate the effect of irrigation frequency and P fertility on seasonal (1 November to 30 April) pasture production for a range of climate conditions using the past 26 years weather data.

The simulation illustrates how pasture production under irrigation varies markedly with climate, irrigation frequency, P fertility status and the ryegrass:clover composition of the sward. Increasing irrigation frequency from I-60 to I-20 increased pasture production, on average, by 1473 kg DM ha⁻¹ (23%) and 1105 kg DM ha⁻¹ (19%) for P-0 and P-40, respectively. For the farmer contemplating the adoption of irrigation, the purchase of a system that allows more frequent irrigation is as significant a consideration as the decision to adopt irrigation itself. On a cautionary note, the model suggests that I-20 irrigation typically increases drainage losses by about 40 mm (42%) compared to I-60 irrigation.

This thesis is dedicated to my father (late Mr.H.A.Mohotti Appuhamy), mother (Mrs.G.Meyhamine) and brother (late H.A.Peries) and teachers, all of them expected me to fulfil this task one day.




11 June 2003

CANDIDATE'S DECLARATION

This is to certify that the research carried out for my Doctoral thesis entitled "*A study of the combined effects of irrigation frequency and phosphorus fertility on summer pasture production*", in the Institute of Natural Resources, Massey University, Turitea Campus, New Zealand, is my own work, and that the thesis material has not been used in part or in whole for any other qualification.

Candidate's Name: Hewana Arachchige Sumanasena

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11 June 2003

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Please insert Ethical Authorisation code(s) here (if applicable): _____

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Date: 11 June 2003 **Date:** 11 June 2003

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