NITRIFICATION AND DENITRIFICATION POTENTIAL OF SOILS UNDER *DALBERGIA SISSO* ROXB. ex DC.

R.F. Fisher and Zahid Javid*

Summary

Shisham (*Dalbergia sissoo* Roxb. ex. DC) is grown under flood irrigation on the Indus Plain of Pakistan. This dinitrogen fixing tree enriches the soil in nitrogen and improves the site upon which it is grown. The low C:N ratio, high summer temperatures and irrigation lead to nitrification rates (7.14 mg NO_3^- –N kg^{-1} soil 24 $days^{-1}$). In addition, water logging leads to denitrification rates as high or higher than the nitrification rates. Consequently irrigation practices that promote anaerobic conditions through water logging, run the very great risk of removing from the site the nitrogen added through shisham cropping.

Introduction

Dinitrogen fixing shisham (*Dalbergia sissoo* Roxb. ex. DC) is major plantation tree, cultivated as a monoculture and also in combination with commercially valuable mulberry (*Morus alba* L.) in the warm temperate thorn woodlands zone (Holdridge, 1967) of Pakistan. Soils of these plantations, after being subjected to canal irrigation, intensive silvicultural operations including complete harvest of aboveground biomass and continuous cultivation of shisham over a period of 120-years, have developed a very narrow C:N ratio (10:1) and high pH range (8.0 ± 0.2). These factors favor high biological ammonification which is followed by nitrification processes (Javid & Fisher, 1989b). In intensively managed forest and agricultural system, especially where leguminous crops have been cultivated, nitrate losses through leaching and denitrification are substantial (Robbins & Carter, 1980; Montaginini *et al.* 1986, Javid & Fisher, 1989c; Hardy & Gibson, 1977). Denitrification in aerobic and anaerobic soil systems has drawn considerable attention in recent years as nitrous oxide's role in atmospheric photochemistry (ozone layer depletion) has been established (Robertson and Tiedje 1988; Murakami *et al.* 1987; Myrold, 1988). field denitrification rates have been correlated to aeration, organic matter content, soil respiration rate, form of added nitrogen, temperature and soil pH. Denitrification under anaerobic conditions is a dominant process, but even in aerobic soil systems a nitrate gradient develops due to nitrification and respiratory oxygen consumption as mineralization of organic matter occurs (Rice *et al.* 1988) resulting in some denitrification losses. Nitrate leaching and denitrification losses have also been correlated to nitrate and carbon concentrations (Grundmann *et al.* 1988), particularly in systems subjected to wetting and drying cycles (Groffman & Tiedje, 1988). Denitrifying populations are adapted to their own environment. Temperate zones have higher nitrate levels in spring and exhibit more seasonal variation in denitrification rates

Dr. R.F. Fisher, Department Head, Department of Forest Resources, College of Natural Resources, Utah State University, Logan, UT 84322-5215.

Dr. Zahid Javid, Research Officer, Punjab Forestry Research and Training Centre, Gatwala, Faisalabad, Pakistan.

than do sub-tropical areas (Powlson *et al.* 1988). We hypothesized that in Pakistani soil systems where high temperatures accompany flooding due to canal irrigation there would be high nitrate losses through leaching and denitrification since nitrifying and denitrifying activity increases during periods of increased temperature and water content (Klubek & Skujins, 1980).

Materials and Methods

Soil samples were collected in Changa Manga plantation, Lahore, Pakistan, from a site that is being cultivated by shisham nursery crop. The soil samples were investigated at Utah State University, USA. The investigation methodology adopted to determine nitrification was by perfusion (percolation). Soil samples were air dried and 80 mg VAMA (Krillium) was added to 40 g of dry soil and mixed thoroughly by adding water until the soil was brought to a "mud" consistency. Soil was then squeezed through a 0.5 mm screen and air dried. For nitrification rate determination soil columns (25 g) in perfusion flasks were percolated under optimal aeration together with water saturation, but no water-logging for a period of 25-days. The perfusate (5 mL) was collected at regular four days intervals and stored at 3°C in a refrigerator. Periodically the water evaporated from the apparatus was replaced to bring water to the original level. Water flow through the soil columns was regulated by vacuum valves to avoid any water logging.

To document denitrification, the same procedure was adopted except water flow through the soil columns was regulated so that a 5–10 mm water layer was maintained above the soil surface constantly. The initial soil ammonium (exchangeable) and nitrate nitrogen was analyzed using the methodology adopted by Hamm *et al.* (1970) from Kamphake *et al.* (1967) and O'Brien and fiore (1962). Disappearance of nitrate nitrogen in water-logged soil was calculated by difference between initial perfusate and nitrate levels in perfusates collected over 25 days. Though the in vitro conditions created may not fully represent the soil water content fluctuations in field soils irrigated by flood irrigation; surely they are good representations of water logged or temporarily water logged conditions in soils with very low organic matter contents (Javid & Fisher, 1989b).

Results and Discussion

Shisham is a dinitrogen-fixing (Javid & Fisher, 1989a) legume, and the turnover of fine roots, nodules and plant residues narrows the soil C:N ratio (Table 1). Our previous studies revealed that in the youngest and most recently feeled and site-prepared stands, nearly all ammonium produced by mineralization was converted to nitrate in situ (Javid and Fisher, 1989b). In these plantations where mean summer temperature are 30–35°C (Bokhari, 1973), the onset of canal irrigation in April-May will not only initiate biological ammonification and nitrification but when anaerobic conditions are caused by flood irrigation also may initiate denitrification. Previously, lysimeter studies in pure shisham plots at Changa Manga plantation have shown substantial nitrate leaching losses from 0—100 cm soil layer (Javid & Fisher, 1989c). No study has been carried out to investigate denitrification *in situ* in these systems having high soil pH (8.0 ± 0.2) high summer temperatures (30—35°C), low organic matter (Table 1), and a narrow C:N ratio. Since

TABLE 1.

Properties of the 0—15 cm layer of soil in the study area.

Acidity pH	Texture	Conductivity mmhos/cm	Extractable P mg kg^{-1}	Extractable K mg kg^{-1}	Organic Carbon %	Total Nitrogen %
8.0 ± 0.2	Silty	0.5 ± 0.1	8.0±0.1	290±3	1.60 ± 0.10	0.13 ± 0.025

these forest systems are not fertilized, no fertilizer amendments were made in these studies, and, nitrification in perfusion flsaks proceeded from 6.36 to 13.50 mg NO_3^-–N kg^{-1} of soil (calculated from leachate analysis) over 24-days period (Fig.1). This nitrification rate of 7.14 mg NO_3^-–N kg^{-1} in vitro as is lower than field incubation rates (Javid & Fisher, 1989b) and is possibly an artifact caused by a combination of factors, such as pressure put up by young seedlings during 1—3 weeks of their establishment on site nutrient reserves at the time of soil sampling and probable denitrification losses caused by the creation of anaerobic micropockets in the soil column by continuous inflow of water to maintain the soil moisture at field capacity during experiment.

In soil column where anaerobic conditions (waterlogged soil) were created, 63% of initial soil nitrate was denitrified as determined through leachate nitrate levels. Within two weeks all the nitrate was lost and leachate samples did not show any nitrate by the end of the incubation period. This indicated that either there was no further nitrification taking place, or that any nitrate produced within the soil column was rapidly denitrified (Fig. 2). Our study concludes that in these irrigated plantations of the Indus Plains, temporary water logging will not only directly decrease the aerobic Bradyrhizobium activity in the soil root environment but will also increase denitrification and deplete the soil nitrogen pool developed overtime by the leguminous shisham cropping.

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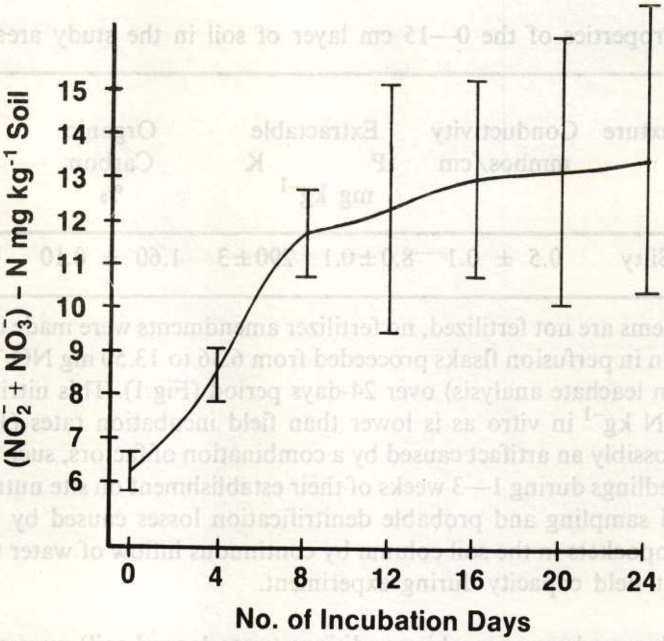
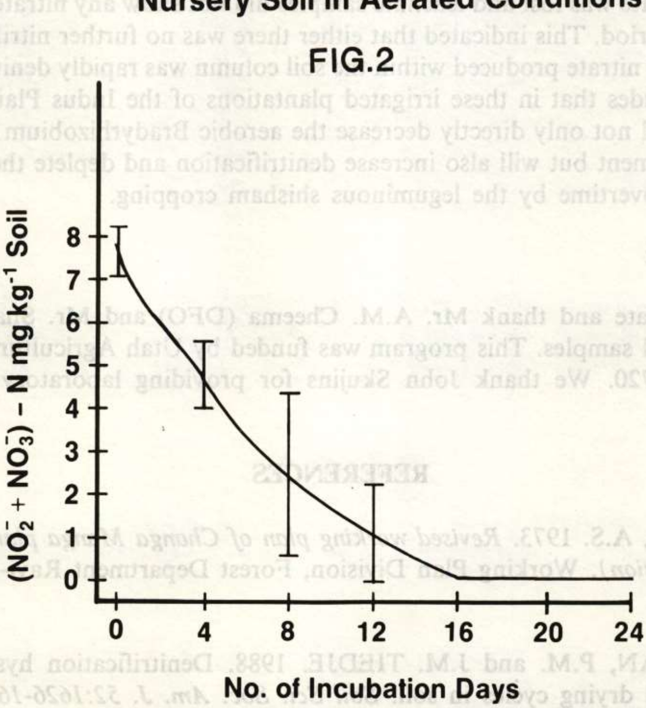
FIG.1



Nitrification Potential of *Dalbegia sissoo* Nursery Soil in Aerated Conditions

FIG.2



Dentrification Potential of *Dalbegia sissoo* Nursery Soil in Waterlogged Conditions

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