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STUDY OF NITROGEN LOSS PATHWAYS IN OIL PALM (*Elaeis guineensis* Jacq.) GROWING AGRO-ECOSYSTEMS ON VOLCANIC ASH SOILS IN PAPUA NEW GUINEA

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

Doctor of Philosophy

in

Soil Science

at Massey University, Palmerston North, New Zealand.

Massey University

Murom Banabas

2007

Abstract

Oil palm is the largest national crop produced in Papua New Guinea. It is grown on over 80,000 ha of young volcanic soils in five Provinces, employs over 12,000 workers and uses >12,000 tonnes of fertiliser to offset nitrogen deficiency which is the most limiting factor to production. Oil palms strip out 160 – 200 kg N ha^{-1} yr^{-1} from the soil. Nitrogen fertilisers account for 60-70 % of all variable production costs but 40-60 % of applied fertiliser cannot be accounted for. Few studies have investigated the amounts of nitrogen lost via leaching, denitrification, volatilisation or as surface runoff in tropical soils and none have been done in Papua New Guinea. Oil palm soils typically have extremely high infiltrabilities (80-8,500 mm hr^{-1}) and receive high annual rainfall which throughfall makes spatially non-uniform.

The objective of this study was to assess and quantify nitrogen losses and suggest strategies that might assist in reducing them and their impact on the environment. The modest facilities available at the two research sites, West New Britain (Dami) and Oro (Sangara) Provinces, meant that no analytical work could be done on-site, so simple but appropriate methods were used to evaluate losses, with samples collected, preserved and sent off-shore for analysis. Large four-palm plots were used to evaluate runoff; a gas trap was used to collect evolved nitrous oxide, and lysimeters, suction cups and finally an *in situ* destructive soil sampling procedure were all used to assess leaching losses and the rate of nitrification of ammonium fertiliser.

Results suggest that under the extreme total annual rainfall at Dami (3,500-4,000 mm) and to a lesser extent at Sangara (2,500-3,000 mm), leaching is the dominant loss pathway, with the rate of loss depending, to some extent, on the rate of nitrate formation and the retentivity of the soil for ammonium, but mainly on the rate at which drainage water is generated.

A leaching model was developed that indicated that the average residence time of nitrogen fertiliser in the root zone (0-50 cm) varied from 21 days in February, at Dami, to 190 days in May, at Sangara.

Acknowledgements

Thanks to my three supervisors at Massey University, Dr Max Turner (Chief Supervisor) for the overall direction and for ensuring that work was on track, Dr David Scotter (Co-supervisor) for his guidance and his help and especially for providing the theoretical basis and Excel spreadsheet for the models in 8.3.4 that so elegantly linked the various elements of this research, and to Dr Neil MacGregor (Co-supervisor) for help with the nitrification and the denitrification trials. Thanks also to my two supervisors on site in PNG, Dr Paul Nelson (2003) and later Dr Mike Webb (2004 – 2006) for guidance and providing useful ideas during the course of this study. All your contributions into this broad range study is much appreciated.

In the Soils and Earth Sciences Group, INR, at Massey University, thanks to Professor Mike Hedley for useful discussions and providing literature materials on aspects of change in soil pH. In the laboratory, thanks to Mr Lance Currie (Laboratory Manager) for facilitating analysis of samples and making available bench space for my laboratory work. Many thanks to Mr Ian Furkert for analysing water samples and to Ms Anne West for help with statistical analysis of data. Thanks also to Mr Bob Toes, Mr Ross Wallace and Ms Glenus Wallace for providing general assistance in the laboratory. Thanks to Mr Mike Bretherton for help with sorting out computer-related issues and Ms Moira Hubbard for assistance with the formatting of this thesis.

Thanks to Dr Surindar Saggar and Mrs Carolyn Hedley at Landcare Research (NZ) for providing assistance with procedure for gas sampling and useful comments on the analysed data.

Many thanks to Mr. Ian Orrell (Director of Research – PNGOPRA) for facilitating funding and allowing me time away from work to conduct this study. Thanks also to Mrs Pole Crompton (Administrator - PNGOPRA) for providing the logistical support. Thanks to EU for providing the funds for the project and also to ACIAR for funding support equipment used in the study.

The work in the field with all the associated difficulties of theft, vandalism, and communication hiccups cannot have been done without dedicated contributions from the two N Loss Teams. At PNGOPRA Higaturu Station, my thanks to Mason Japara and David Joe and those who helped, Rex Suma and Andy Ullian, Ambex Raynold and William Sirabis (Trainee Unitech Student), and at Dami Station, to Hanson Hinjik, Jeffrey Tamunda, Mark Erick, Maori Nara, Peter Mapa, Levi Atam, Daniel Kuri and Norma Konimor (Supervisor). Thanks for all your keenness and work even late into the night and early hours of mornings to monitor trials during the wet season. Your contributions are much appreciated.

Thanks to Rose Toby and Janet Suru for timely collation of weather data and doing data entries for me when required. Thanks also to Serah Naemon from Ramu Sugar for providing useful weather data from the valley. Thanks to Steven Nake, Rachael Pipai and James Kraip, four field supervisors; Paul Simin, Graham Bonga, Pauline Hore and Graham Dikop for making available their time and workers as, and when, required. Thanks to Fredius Julius, Agatha Owens, Elizabeth Kibikibi and Joe Rusu for providing the required logistical support.

To OPIC officers, at Popondetta thanks for allowing us to collect tank water at Igora OPIC Station. At Nahavio, thanks for the use of dumpy level at Dami.

Higaturu Oil palms, thanks to the Building Department for use of the dumpy level and the Mill and Vehicle workshops for assisting with welding of metal pipes and cutting of drums and thanks to the field department for providing the excavator at short notices. Thanks to HOP (Building and Mill and VWS workshops) for assisting with welding of metal pipes and cutting drums for various experiments. Thanks for allowing me to conduct the experiment on your plantation.

Thanks to the Management of Dami OPRS for allowing me to conduct experiments in the plantation fields. Thanks to Ruth Pipai and Judith Makai for providing the Dami weather data. Assistance form Mr and Mrs Betitis (Agronomy Section), Mr Patrick Mungore (Station Manager), Mr Harry Brook (former Station Manager) and Dr. Simon Lord (Head of OPRS) and the Librarian, Maria Luanga, is much appreciated.

At Massey University, TVL Building, thanks to the other postgraduate students for useful discussions and help while writing; Jagratti, Monica, Tham, Bambang and Tin.

A special thanks to my wife (Nambua) and our four children (Enzeng, Serah, Yandi and Elizah) and my little friend Bana for putting up with my regular away trips from home. Thanks to all our family friends at Popondetta for supporting my family while I was away studying; Pastor Ken Tinzanga, Yasaking Bobby, Awa Erap, Feberth Nasine, Veronica Owedo, Rex Suma, and Yaso and Jacob families, Ross and Cath Safitoa and Dambi and many others not mentioned. My parents at home for their moral support and a special tribute to my younger brother (Nanaim), who passed away during my study in NZ and was not able to attend his funeral.

Finally, I dedicate this thesis to the Papua New Guinea Oil Palm Industry.

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List of abbreviations and symbols

AMC	Ammonium chloride
AMN	Ammonium nitrate
Br^-	Bromide ion
BZ	Between zone
CDE	Convection dispersion equation model
Cl^-	Chloride ion
CLT	Convective lognormal transfer function model
DAP	Diammonium phosphate
FP	Frond pile
FT	Frond tip
HP	Harvest path
K	Kina (PNG currency, 1 kina = NZ$0.47
LAI	Leaf area index
N	Nitrogen
NBPOL	New Britain Palm Oil Limited
NH_4^+-N	Ammonium nitrogen
NI	New Ireland
NO_3^--N	Nitrate nitrogen
NZ	New Zealand
OPIC	Oil Palm Industry Corporation
OPRS	Oil Palm Research Station (NBPOL)
pdf	Probability density function
PNG	Papua New Guinea
PNG OPRA	Papua New Guinea Oil Palm Research Association
SOA	Sulphate of ammonium
WC	Weeded circle
WFPS	Water-filled pore space
WNB	West New Britain

List of Symbols

Symbol	Description	Dimensions
a	Exponential decay constant	T^{-1}
C	Normalised ammonium N concentration	-
C	Capillary rise	L
C_o	Normalised concentration of ammonium N when $t = 0$	-
C_s	Solute concentration in soil solution	$M\ L^{-3}$
C_{tot}	Total solute concentration	$M\ L^{-3}$
C	Average solute concentration	$M\ L^{-3}$
D	Dispersion coefficient	$L^2\ T^{-1}$
D	Surplus water	L
E	Evaporation	L
E_{ff}	Effective evaporation	L
E_r	Reference crop evaporation	$L\ T^{-1}$
f	Porosity	-
I	Added water or throughfall	L
I	Water input to the soil	L
I_c	Calibrated throughfall	L
I_m	Leaching water	L
I_r	Interception	L
J_w	Soil water flux	$L^3\ L^{-2}\ T^{-1}$
M	Fertiliser applied onto soil surface	$M\ L^{-2}$
M_s	Mass of soil solid	M
M_w	Mass of water	M
n	Sunshine hours	T
ρ_b	Soil bulk density	$M\ L^{-3}$
ρ_s	Soil particle density	$M\ L^{-3}$
P	Precipitation	L
θ	Volumetric water content – theta	$L^3\ L^{-3}$
θ_{FC}	Volumetric water content at field capacity	$L^3\ L^{-3}$
θ_{PWP}	Volumetric water content at permanent wilting point	$L^3\ L^{-3}$

Symbol	Description	Dimensions
θ_{SP}	Volumetric water content at stress point	$L^3 L^{-3}$
q_s	Solute flux density (mass of solute carried across a unit cross-sectional area per unit time)	$M L^{-2} T^{-1}$
q_w	Darcy flux density (volume of water flowing across a unit cross sectional area per unit time)	$L^3 L^{-2} T^{-1}$
R	Retardation factor	-
R	Surface runoff	L
S	Deep drainage	L
S_f	Stemflow	L
t	Time	T
$t_{1/2}$	Half life	T
T	Throughfall	L
μ	Mean	-
u_z	Wind speed at height z	$L T^{-1}$
V	Average speed of solute (non-adsorbed) down through a profile	$L T^{-1}$
V	Mean water velocity	$L T^{-1}$
V_t	Volume of soil	L^3
V_w	Volume of water	L^3
w	Gravimetric water content	$M M^{-1}$
W	Equivalent depth of soil water	L
W_n	Soil water storage in the root zone, relative to field capacity, on day n	L
W_R	Readily available water	L
W_T	Total plant available water	L
z	Soil depth	L
Z	Height above sea level	L
Z	Depth of soil in lysimeter	L
Z_m	Leaching depth	L