Gentile, R. et al., 2016. Nutrient management of avocado trees on small holder farms in the Central Highlands of Kenya. In: *Integrated nutrient and water management for sustainable farming*. (Eds L.D. Currie and R.Singh). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 29. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 5 pages.

NUTRIENT MANAGEMENT OF AVOCADO TREES ON SMALL HOLDER FARMS IN THE CENTRAL HIGHLANDS OF KENYA

R. Gentile[1], R. Fullerton[1], G. Thorp[1], A. Barnett[1], C. Clark[1], J. Campbell[1], M. Gitahi[2], and B. Clothier[1]

[1]*The New Zealand Institute for Plant & Food Research Limited*
[2]*Olivado Limited*

Introduction

Plant & Food Research is engaged in a project in Kenya in partnership with the company Olivado Ltd, which produces avocado oil from fruit from over 1300 small-holder farms. The project is funded by the New Zealand Ministry of Foreign Affairs and Trade as part of the New Zealand Aid Programme. In the project, we are developing sustainable production systems to improve the supply of high quality organically-grown avocados. Improved avocado production will increase the revenue stream for these small-holder farmers. One of our activities is to improve the nutrient status of avocados grown under current farming practices.

Nutrient survey

Avocados are grown in the Central Highlands of Kenya and monitoring farms have been established at the low, mid, and high altitudes in the Kandara valley and around the towns of Embu and Nyeri. Soil and plant nutrient analyses were made on each monitor farm, and on a number of other orchards in the main production regions to assess the current fertility status of the farms.

Soils in this region are classified as Nitisols, deep red soils with a nut-shaped structure and high iron content (Jones et al. 2013). These soils have low concentrations of organic matter and low pH (Figure 1). Our soil sampling revealed a decrease in pH and increase in organic matter with altitude in the Kandara valley. This observed gradient is probably attributable to the higher amounts of rainfall received in the higher altitudes of the valley, which can increase organic matter production and leach base cations from the soil. The cation exchange capacity (CEC) of these soils is in the medium range because of the high clay content (75-80 %) of these soils.

Very high
High
Medium
Low
Very low

	pH	Organic matter	CEC	Base saturation
		%	me/100g	%
Medium range	6.0-6.6	7-17	12-25	60-85
Low Kandara				
F02-001	6.2	5.9	23	74
F02-368	6.3	4.3	22	71
F01-078	5.3	5.4	17	47
F01-431	5.4	5.3	16	46
Mid Kandara				
F02-187	5.0	5.5		
F02-189	5.0	4.4	15	44
F02-218	4.9	5.4		
High Kandara				
F01-606	4.6	8.3		
F01-651	5.1	9.7	19	18
F02-194A	4.4	12.9		
Embu				
F03-007	5.8	5.0	20	63
F03-011	6.3	4.1	18	78
F04-019 A	6.2	5.4	23	23
Nyeri				
F07-016	6.3	5.8	24	82
F07-034	5.3	4.5	19	53
F07-059	6.0	5.8	24	75

Figure 1. Soil chemical properties of avocado farms located in high, mid and low altitudes of the Kandara valley and the towns of Embu and Nyeri, Kenya. Mean property values are colour coded from high to low ranges (R J Hill Laboratories, Hamilton). CEC = cation exchange capacity.

Soil and leaf nutrient analyses showed very low phosphorus in all soils and a relatively low nitrogen content particularly at the lower altitudes (Figure 2). Boron, an essential nutrient for successful avocado production, is low in all areas. One of the greatest challenges to improve avocado productivity is finding ways to improve soil nutrient status and tree nutrition under an organic growing system.

Very high
High
Medium
Low
Very low

	N	P	K	Ca	Mg	Mn	Zn	Cu	B
	%	mg/L	me/100 g	me/100 g	me/100 g	mg/L	mg/L	mg/L	mg/L
Medium range	0.3-0.6	25-50	0.5-0.8	7.0-18.0	1.0-3.0	50-400	2-10	1.0-5.0	4.0-6.0
Low Kandara									
F02-001	0.32	6	2.0	10.8	4.1	1862	54	3.8	1.8
F02-368	0.24	7	3.1	9.5	3.3	1953	36	2.8	2.0
F01-078	0.29	7	0.7	5.3	2.3				
F01-431	0.28	4	0.7	4.2	2.4	1538	15	8.4	1.3
Mid Kandara									
F02-187	0.27								
F02-189	0.23	5	0.5	4.0	1.9	541	5	4.3	1.2
F02-218	0.28								
High Kandara									
F01-606	0.40								
F01-651	0.49	9	0.5	3.6	1.0	89	5	1.6	1.0
F02-194A	0.63								
Embu									
F03-007	0.23	9	0.6	7.4	4.3	1928	16	2.4	1.5
F03-011	0.19	10	1.9	8.5	3.5	1530	9	1.7	1.2
F04-019 A	0.29	6.2	1.4	11.6	4.0	1275	31	25.6	1.5
Nyeri									
F07-016	0.30	12	1.3	13.5	5.2	1380	29	3.0	1.7
F07-034	0.26	15	1.1	5.8	3.0	1556	10	9.8	1.5
F07-059	0.36	6	3.2	9.8	4.6	2280	83	4.7	2.0

Figure 2. Soil nutrient analyses of avocado farms located in high, mid and low altitudes of the Kandara valley and the towns of Embu and Nyeri, Kenya. Mean nutrient values are colour coded from high to low ranges (R J Hill Laboratories, Hamilton).

Nutrient budgets

The majority of the small-holder farms supplying avocados to Olivado use organic production methods. This means organic amendments such as plant residues, composts and animal manures are required to replenish the nutrients that are exported from the farms and thus to improve soil fertility.

Yield and fruit nutrient concentration data are being used to assess the quantity of nutrients being exported in the harvested crop (Table 1).

Table 1. Quantities of major elements exported from an avocado tree producing 100 kg of fruit.

Nutrient	(g per tree)
Nitrogen	300
Phosphorus	50
Potassium	500

Using that data and by analysing the nutrient concentrations of locally available organic amendments, nutrient budgets are being prepared to provide recommendations on the amount of organic material needed to sustain soil fertility. For example, nutrient concentrations of manure vary by animal source (Table 2, Lesschen et al. 2007).

Table 2. Fresh weight nutrient composition of different animal manures (adapted from Lesschen et al. 2007).

Nutrient	Cow	Goat	Poultry
Nitrogen (%)	0.76	0.79	1.08
Phosphorus (%)	0.15	0.20	0.39
Potassium (%)	0.67	0.50	0.35

A single cow is estimated to produce 1550 kg of manure per year (Lesschen et al. 2007). Using the manure produced by a single cow as an example, we can calculate the amount of cow manure needed to replace the nutrients harvested in a 100-kg avocado crop (Table 3), and the potential number of trees that a single cow may fertilise. For example, if all manure is returned to the orchard, manure from a single cow may replace the nitrogen exported by 39 trees, or the phosphorus removed from the farm by 46 trees. The actual rate of return of manure to the orchard varies greatly between farms and a proportion will be diverted for use on other crops. Nevertheless livestock have the potential to provide nutrients for a significant number of avocado trees.

Table 3. Nutrient replacement calculations for avocado trees yielding 100 kg of fruit.

Nutrient	Amount of cow manure to replace exported nutrients (kg per tree per year)	Number of trees manure from one cow can fertilise in a year (No. trees)
Nitrogen	39	39
Phosphorus	33	46
Potassium	75	21

It is important to note that simply replacing the quantities of nutrients exported in harvested fruit will not correct the existing low soil concentrations of nitrogen, phosphorus, and boron measured under current practices. The nutrient composition of organic material available both on-farm and off-farm will be determined to enable more accurate recommendations to be made on fertility management both in terms of exported nutrients and enhancing basic soil fertility.

These nutrient budgets and recommendations will be incorporated into a Decision Support Tool to assist small-holder farmers in enhancing their soil and plant nutrition.

Acknowledgement
This work is supported by the New Zealand Ministry of Foreign Affairs & Trade and Olivado Limited.

NEW ZEALAND
MINISTRY OF FOREIGN AFFAIRS & TRADE
Aid Programme

References

Jones, A., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Dewitte, O., Gallali, T., Hallett, S., Jones, R., Kilasara, M., Le Roux, P., Micheli, E., Montanarella, L., Spaargaren, O., Thiombiano, L., Van Ranst, E., Yemefack, M., Zougmore, R., (eds.) 2013. Soil Atlas of Africa. European Commission, Publications Office of the European Union, Luxembourg. 176 pp.

Lesschen, J.P., Stoorvogel, J.J., Smaling, E.M.A., Heuvelink, G.B.M., Veldkamp, A. 2007. A spatially explicit methodology to quantify soil nutrient balances and their uncertainties at the national level. Nutr. Cycl. Agroecosyst. 78, 111-131.