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COCONUT HUSK ASH AS A FERTILIZER FOR COCONUT PALMS ON PEAT

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SUMMARY

We demonstrated experimentally that coconut husk ash is an excellent mineral fertilizer for immature coconut hybrids on developed peat, providing potassium (K) in particular. Coconut husk ash performed as well as potassium chloride (KCl) in a proportion of 2–2.5 to 1. At four years, 99% of coconut palms fertilized with husk ash, 92% of coconut palms fertilized with KCl and 26% of control palms were sexually differentiated. The cumulative yield in the first two harvesting years more than trebled between control palms (26 nuts per tree) and the palms fertilized with KCl (93 nuts per tree) or husk ash (105 nuts per tree). This is an important result, given the intensity of K deficiency and the increasing cost of imported fertilizers. Although coconut husk ash will never totally replace K fertilizer, it can recycle a substantial proportion of nutrients in a coconut plantation. It now remains to optimize its use on an estate level, by examining the feasibility and cost-effectiveness of its mass production and determining conditions for maximum efficiency.

INTRODUCTION

Coconut husk is a by-product of coconut growing that has long been used for a variety of purposes. Its fibre is used industrially as a raw material for ropes, mattresses, stuffing for chairs and insulation. Defibring waste (cocopeat) is greatly appreciated as a horticultural growing medium. The hygroscopic properties of coconut husk make it a good water absorbent material that is very effective in increasing the water-holding capacity of a soil in dry periods (Liyanage *et al.* 1993; Sherin *et al.* 2004; Subramanian *et al.* 2006). It can also concentrate nutrients, particularly potassium (K) and chlorine (Cl), which can be recycled in coconut plantations when nuts are dehusked in the field and the husks are left to rot on site (Ouvrier, 1984; Ouvrier *et al.* 1978; 1985; Teoh *et al.* 1986).

However, leaving husks to rot at the foot of coconut palms on peat soils has two major negative effects: firstly, it causes a nitrogen (N) deficiency in neighbouring palms, and heaps of husk fragments provide shelter for the insect pest *Sufetula*, whose larvae attack coconut roots (Bonneau *et al.*, 2007).

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Table 1. Analysis of ash of coconut husk as dry matter weight (2002).

Nutrient	%	ppm
N	0.014	
P	0.89	
K	25.6	
Ca	1.34	
Mg	4.58	
Na	4.11	
Cl	8.76	
S	0.56	
SiO_2	8.92	
Fe	1.64	
B		323
Cu		79
Zn		112

All values are means of four composite samples.

In order to benefit from the advantages offered by coconut husk without suffering the drawbacks, we tested coconut husk ash as a fertilizer, and as a possible substitute for imported fertilizers such as KCl.

MATERIALS AND METHODS

The estate (18 000 hectares) is planted on deep peat on the east coast of the island of Sumatra (Riau Province, Indonesia) and belongs to the Riau Sakti United Plantations company (RSUP).

Planting material on the estate consists mostly of PB 121 hybrids (MAWA), at a density of 180 palms ha^{-1} (8 m apart in a staggered equilateral triangle design). The basic unit is a block of 50 ha (500 × 1000 m). The water-table is controlled in the fields by a network of canals and field drains.

Field trials were carried out to test *in situ* the effect of treatments applied to coconut palms (Bonneau *et al.* 2007). Coconut husk ash is obtained by simply burning fresh coconut husk, either directly in the field after dehusking harvested nuts, or in an open-air kiln with a roof from which ash is recovered via a grate in the convex bottom.

With the latter method, around 2.5% of ash is recovered from fresh husk, corresponding to known values (Georgi, 1941). We analysed the chemical composition of coconut husk ash, as shown in Table 1. In our case, a mixture of husks was used from different plots in the plantation, bearing in mind that the chemical composition of husk reflects that of the palms from which it comes, as will be seen later. Coconut husk ash at RSUP was found to contain a large amount of K (26%), silica (SiO_2) and Cl (9% each), and virtually no N. This composition, particularly the K content, tallies with analyses we carried out ourselves in Mozambique in 2000, and with analyses in Malaysia (Georgi, 1941).

Measuring the fertilizing effect of coconut husk ash

The effect of coconut husk ash has been measured in two field trials.

Trial 1: This trial tested two locally produced fertilizers: coconut husk ash and aquatic plants (mostly water hyacinths), which clog the canals, after collecting and drying in the open air. They were compared to two controls, one without fertilization and the other receiving optimum fertilization with imported fertilizers (urea, rock phosphate and especially KCl). All the coconut palms in the trial also received the same quantities of trace elements in the first and second years after planting as they are essential on peat, especially copper (Bonneau *et al.* 1993; Ochs *et al.* 1993).

The aim was firstly to discover whether the two local fertilizers were able to release nutrients beneficial to coconut palms, whether they had any negative secondary effects, and to what degree they could be used to replace imported mineral fertilizers for future use on an estate scale.

Trial 1 was planted in 2002 on deep peat with a water-table maintained at a depth of around 1 m. The previous crop was pineapple grown in a monoculture for three years running after forest clearance and land improvement (drainage and compaction). The experimental design was a randomized complete block with four treatments: no fertilization, aquatic plants, coconut husk ash and imported fertilizers, and six replicates. Each unit plot contained 36 coconut palms (6 rows of 6), of which 16 palms (4 rows of 4) were used for data collection. Ninety-four per cent of the planting material was the Khina 2 hybrid (Malayan Yellow Dwarf × Palu Tall); the remaining 6% was the PB 121 hybrid (Malayan Yellow Dwarf × West African Tall), distributed uniformly per treatment. In order to minimize *Sufetula* pest pressure, the palms in the trial were separated from neighbouring plots of mature palms by a 150-m wide strip of pineapple plants in a monoculture. Three cycles of intercropped pineapples were also grown in the inter-rows of the immature coconut palms. The trial lasted five years.

Fertilizers were applied at the frequency specified in the schedule used for the estates, at increasing rates: five applications in the first year, three applications in the second year, three applications in the third year, and an annual application from the fourth year onwards. Annual fertilizer quantities applied are shown in Table 2. Rates were calculated at the equivalent quantity of K theoretically provided by KCl in the standard fertilization control.

The following variables were also measured as plot means:

- vegetative growth: collar girth, frond length, number of green fronds per coconut palm and the leaf area index
- flowering: % of sexually differentiated palms, number of female flowers per inflorescence, number of set nuts per bunch in the axil of leaf 14
- yield: number of nuts per palm per year
- nutritional status: an annual leaf analysis.

Trial 2: This trial has a subdivided block design (split plot). It takes into account the results obtained in trial 1, among other things, and is testing four types of fertilization on immature coconut palms as the main treatments: coconut husk ash, KCl, NaCl and a 50:50 KCl:NaCl mixture. Each main treatment has two subdivisions for the

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Table 2. Application rates of locally produced fertilizers and mineral fertilizer used in treatments of coconut palms in RSUP Trial 1.

	Micro-nutrients†			
Planting year	Borax	Iron sulphate	Copper sulphate	Zinc sulphate
1	10	50	170	10
2	20	0	0	0
Total	30	50	170	10

	Treatment fertilizer‡					
				Standard mineral fertilizer		
	No fertilizer	Ash§	Aquatic plants¶	Urea	Rock phosphate	KCl
1	0	1.05	2.6	0.4	0.2	0.6
2	0	3.6	7.5	0.4	1	1.8
3	0	6	12	0.4	0	3
4	0	5	25	0.5	1	2.5
5	0	6.25	30	0	0	2.5
Total	0	21.9	77.1	1.7	2.2	10.4

†Overall micro-nutrients: rates in g fertilizer per palm.
‡Treatment fertilizers: rates in kg fertilizer per palm.
§Coconut husk ash.
¶Air-dried canal plants.

rate: a full rate and a half rate. As previously, all the coconut palms received the same quantities of trace elements as a top dressing, along with a top dressing of urea and rock phosphate to prevent any mineral deficiencies other than for the nutrients being tested, namely Cl, K and Na.

The purpose of this second trial is to develop a fertilizer schedule for immature hybrid coconut palms on developed deep peat, testing fertilizers that appeared to be efficient and inexpensive in earlier trials.

Trial 2 was planted in 2006, near trial 1, on deep peat with a water-table maintained at a depth of around 1 m. The previous crop cover was pineapple grown in a monoculture for three years running after forest clearance and land improvement (drainage and compaction). The experimental design is a randomized complete block subdivided into four main treatments (see above), two subdivisions (see above) and five replicates. Each unit plot contains 36 coconut palms (6 rows of 6), of which 16 palms (4 rows of 4) are used for data collection. The planting material is the PB 121 hybrid (Malayan Yellow Dwarf × West African Tall). As in the previous trial, the palms are separated from neighbouring plots of mature palms by a strip of pineapple monocultures, in order to minimize *Sufetula* pest pressure. Pineapples are also planted in the interrows of the young coconut palms. The trial is scheduled to run for four to five years.

Fertilizers are applied at the frequency specified by the estate schedule, at increasing rates in line with age and respecting the experimental protocol: five applications in the

Table 3. Application rates of micro-nutrients and macro-nutrients (a) and locally produced fertilizers and mineral fertilizer (b) used in treatments of coconut palms in RSUP Trial 2.

(a)

Planting year	Borax	Iron sulphate	Copper sulphate	Zinc sulphate
	Micro-nutrients†			
1	10	50	170	10
2	20	0	0	0
Total	30	50	170	10
	Macro-nutrients‡			
	Urea		Rock phosphate	
3	1		0.5	

(b)

Planting year	Ash¶		KCl		NaCl		50:50 KCl:NaCl	
	Treatment fertilizers§							
	0.5	1	0.5	1	0.5	1	0.5	1
1	1.225	2.45	0.525	1.05	0.525	1.05	0.525	1.05
2	2.625	5.25	1.05	2.1	1.05	2.1	1.05	2.1
3	3.75	7.5	1.5	3	1.5	3	1.5	3
Total	7.6	15.2	3.075	6.15	3.075	6.15	3.075	6.15

†Overall micro-nutrients: rates in g fertilizer per palm.
‡Overall macro-nutrients: rates in kg fertilizer per palm.
§Rates in kg fertilizer per palm (0.5: half rate; 1: full rate).
¶Coconut husk ash.

first year, three applications in the second year, two applications in the third year, then an annual application is scheduled in the fourth and fifth years. The annual fertilizer quantities are shown in Table 3.

The same variables are being measured as in the previous trial.

RESULTS

All the variables in the first trial showed similar patterns indicating that coconut husk ash performed well when compared to a standard fertilizer primarily consisting of KCl, in a proportion of 2 to 2.5 kg of coconut husk ash for 1 kg of KCl. The same trend was found for vegetative growth (Figure 1 and Table 4), flowering (Figure 2) and yields (Table 5).

The coconut palms without fertilization fell behind considerably and although the palms fertilized with aquatic plants grew and yielded a little better than the unfertilized control palms, they lagged way behind the best two treatments.

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Table 4. Vegetative growth of coconut palms in RSUP Trial 1.

Variable	Age of palms (months)	Treatment: No fertilizer	Ash†	Aquatic plants‡	Standard mineral fertilizer	*s.e.*
Collar girth (m)	36	1.10	1.55	1.25	1.48	0.09
	60	1.27	1.58	1.31	1.58	0.07
Number of green fronds per palm	36	14.8	23.6	17.1	22.5	1.52
	60	22.1	30.3	23.5	29.3	1.63
Length of frond (m)	36	3.40	4.42	3.93	4.37	0.18
	60	4.65	5.47	5.07	5.50	0.21
Leaf area index	36	0.49	1.55	0.78	1.40	0.19
	60	1.50	2.77	1.82	2.68	0.26

†Coconut husk ash.
‡Air-dried canal plants.

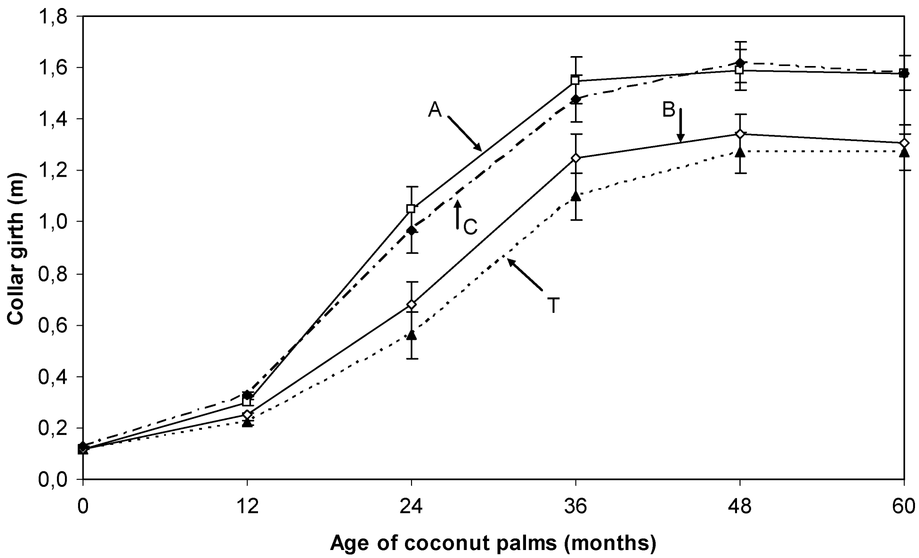

Figure 1. Collar girth of coconut palms treated with coconut husk ash, aquatic plants and mineral fertilizer in RSUP Trial 1. T: control treatment (no fertilizer); A: fertilized with coconut husk ash; B: fertilized with air-dried aquatic plants; C: fertilized with imported standard fertilizers. Vertical bars show *s.e.*

For example (Figure 2), for the first flowering 50% sex-differentiation was reached after 55 months in the unfertilized control palms, as opposed to 47 months in the palms fertilized with aquatic plants, 43 months in the palms fertilized with KCl and 39 months in the palms fertilized with husk ash. The same figure shows that after 48 months virtually all (99%) the coconut palms fertilized with coconut husk ash were sexually differentiated, closely followed by the palms fertilized with KCl (92%); the palms fertilized with dried aquatic plants trailed far behind (57%) and the control palms came last (26%).

Table 5. Production of nuts from palms treated with coconut husk ash, aquatic plants and mineral fertilizer in RSUP trial 1.

	Treatment				
Planting year	No fertilizer	Ash†	Aquatic plants‡	Standard mineral fertilizer	*s.e.*
5	3.9	36.9	8.1	26.7	3.5
6	21.8	67.7	31.4	66.3	7.4
Total	25.7	104.6	39.5	93.0	

†Coconut husk ash.
‡Air-dried canal plants.

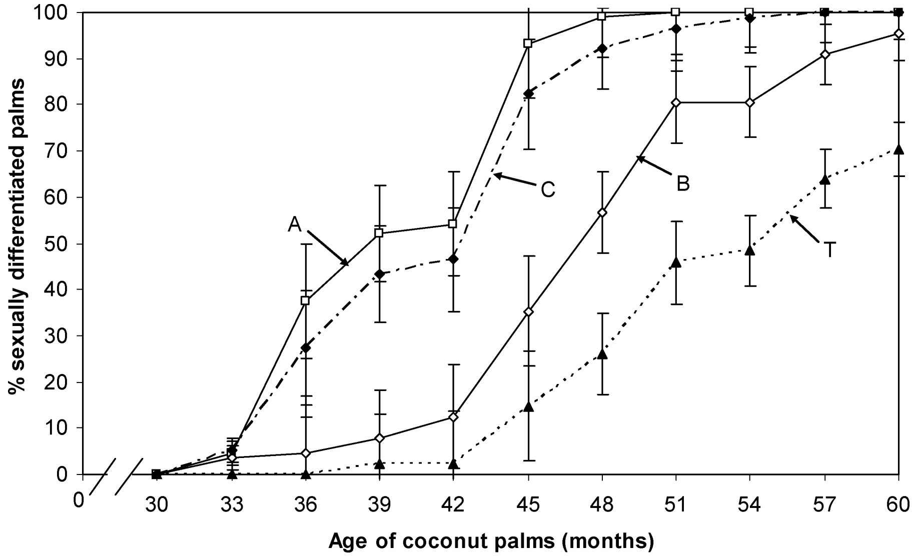

Figure 2. Flowering (cumulative percentage of sex-differentiated palms) v. age of coconut palms treated with coconut husk ash, aquatic plants and mineral fertilizer in RSUP Trial 1. T: control treatment (no fertilizer); A: fertilized with coconut husk ash; B: fertilized with air-dried aquatic plants; C: fertilized with imported standard fertilizers. Vertical bars show *s.e.*

Another example is given by the cumulative yield in the first two harvesting years (Table 5), which more than trebled between the control palms without fertilization and the palms fertilized with KCl or husk ash, while the palms fertilized with aquatic plants produced slightly more than the unfertilized control palms but remained well behind the best two treatments.

When correlating the growth and yields of the coconut palms with their nutritional status revealed by a leaf analysis, we found that it was a K deficiency that had caused the coconut palms without fertilization, or those fertilized with aquatic plants, to fall behind (Table 6). Coconut husk ash provides as much K and Cl as KCl, with non-limiting contents for the other nutrients (data not shown), and also SiO_2, a nutrient

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Table 6. Mineral analysis of leaves from coconut palms treated with coconut husk ash, aquatic plants and mineral fertilizer in RSUP Trial 1.

Age of palms (years)	Treatment				
	No fertilizer	Ash[†]	Aquatic plants[‡]	Standard mineral fertilizer	*s.e.*
			Potassium[§]		
3	0.574	1.261	0.716	1.467	0.054
4	0.639	1.056	0.536	1.264	0.047
5	0.658	1.151	0.657	1.211	0.059
			Chlorine[§]		
3	0.389	0.595	0.346	0.748	0.020
4	0.459	0.734	0.458	0.854	0.029
5	0.460	0.688	0.446	0.768	0.043
			Silicon dioxide[§]		
3	0.195	0.595	0.188	0.160	0.021
4	0.194	0.576	0.201	0.171	0.034
5	0.209	0.505	0.196	0.169	0.035

[†]Coconut husk ash.
[‡]Air-dried canal plants.
[§]Nutrient content of leaf 14 as % of dry matter.

that proves to be inert since the difference in SiO_2 content between the husk ash and KCl treatments was not reflected in growth or yields.

Coconut husk ash therefore proved to be a very efficient fertilizer in trial 1. The nutrients it contains were effectively taken up, especially K and Cl, which coconut palms require most of all in this environment. This resulted in balanced mineral nutrition as good as that in palms receiving optimum fertilization with a range of single fertilizers.

Trial 2 is currently confirming that result perfectly. In the same proportion of 2 to 2.5 for 1, coconut husk ash is proving to be as efficient a fertilizer as KCl, which is the reference for optimum fertilization. This can be seen for all the variables measured: vegetative growth (Table 7), flowering (Figure 3) and leaf analysis (Table 8).

The range of responses to treatments is less in trial 2 than in trial 1 because trial 1 tested different types of fertilizer of unknown efficiency in comparison with a known reference, whereas trial 2 is testing fertilizers of known efficiency, which we knew would be effective to some degree.

It is worth noting that vegetative growth is as good in the palms fertilized with husk ash as in those fertilized with KCl (Table 7), and the onset of flowering in the palms fertilized with husk ash is excellent (Figure 3). At 36 months, 61% of the young hybrid coconut palms fertilized with husk ash are sexually differentiated, as opposed to 50% of the young palms fertilized with KCl, and 39% of the young palms fertilized with NaCl.

Table 7. Vegetative growth and nut set (as number of set nuts per bunch in the axil of frond 14) in coconut palms treated with locally produced fertilizers and mineral fertilizer, at two rates, in RSUP Trial 2.

(a) Means per combination

Variable	Age of palms (months)	Ash		KCl		NaCl		50:50 KCl:NaCl	
		0.5	1	0.5	1	0.5	1	0.5	1
Collar girth (m)	24	0.99	1.03	0.94	0.97	0.79	0.89	0.80	0.85
	42	1.53	1.51	1.52	1.57	1.38	1.39	1.42	1.50
Number of green fronds	24	14.1	14.4	13.7	14.0	12.8	13.2	12.7	13.3
per palm	42	24.1	24.2	23.6	24.3	22.3	23.5	22.4	23.7
Length of frond (m)	24	2.70	2.81	2.62	2.70	2.24	2.48	2.37	2.42
	42	4.78	4.67	4.55	4.64	4.19	4.26	4.26	4.41
Leaf area index	24	0.61	0.67	0.57	0.63	0.42	0.46	0.43	0.49
	42	2.06	2.14	1.95	2.15	1.56	1.72	1.74	1.94
Nut set	42	5.1	6.5	3.9	6.4	2.2	4.3	2.1	3.3

(b) Means per main treatment

Variable	Age of palms (months)	Main treatment				*s.e.* main treatment
		Ash	KCl	NaCl	50:50 KCl:NaCl	
Collar girth (m)	24	1.01	0.96	0.84	0.82	0.21
	42	1.52	1.55	1.38	1.46	0.12
Number of green	24	14.3	13.9	13.0	13.0	1.43
fronds per palm	42	24.2	24.0	22.9	23.1	1.41
Length of frond (m)	24	2.76	2.66	2.36	2.40	0.29
	42	4.73	4.60	4.23	4.34	0.41
Leaf area index	24	0.64	0.60	0.44	0.46	0.21
	42	2.10	2.05	1.64	1.84	0.23
Nut set	42	5.8	5.1	3.3	2.7	2.1

(c) Means per subdivision

Variable	Age of palms (months)	Subdivision†		*s.e.* subdivision
		0.5	1	
Collar girth (m)	24	0.88	0.93	0.02
	42	1.46	1.49	0.11
Number of green	24	13.3	13.7	0.45
fronds per palm	42	23.1	23.9	0.31
Length of frond (m)	24	2.48	2.60	0.05
	42	4.45	4.50	0.14
Leaf area index	24	0.51	0.56	0.08
	42	1.83	1.99	0.11
Nut set	42	3.3	5.1	0.6

†Subdivisions. 0.5: half rate; 1: full rate.
N.B. No interactions were observed at 24 or 42 months.

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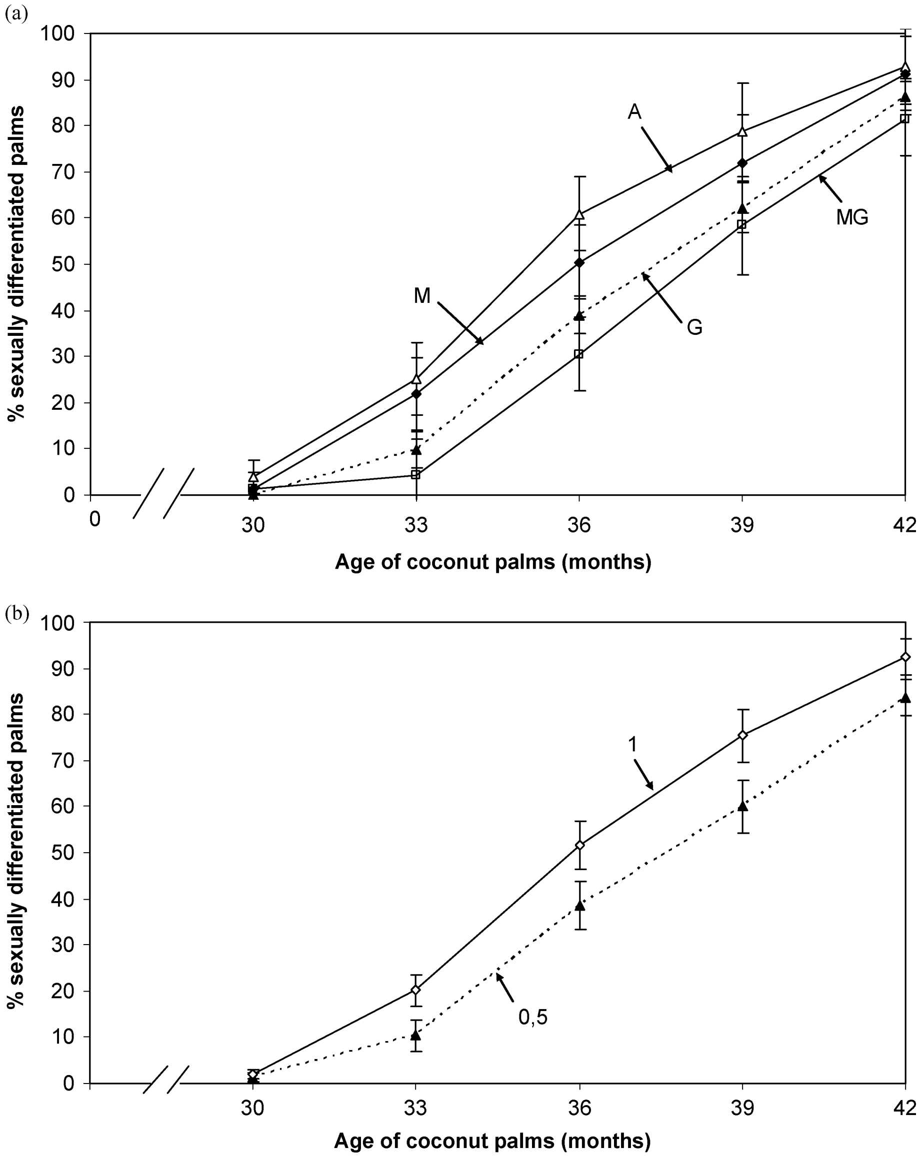

Figure 3. Flowering (cumulative percentage of sex-differentiated palms) v. age of coconut palms treated with coconut husk ash, KCl, NaCl and 50:50 KCl:NaCl mixture in RSUP Trial 2. a: Main fertilizer treatments; A: fertilized with coconut husk ash; M: fertilized with KCl; G: fertilized with NaCl; MG: fertilized with 50% KCl, 50% NaCl. b: Full and half rate fertilizer treatments (sub divisions). Vertical bars show *s.e.*

The mineral leaf analysis at three years (Table 8) shows good K and Cl contents in the main treatment with husk ash, confirming that these two nutrients are easily solubilized and effectively taken up by the coconut palms.

Also worth noting is the significant subdivision effect for most of the variables measured. For all the main treatments combined, the palms receiving a full fertilization

Table 8. Mineral analysis of leaves from coconut palms treated with locally produced fertilizers and mineral fertilizer, at two rates, in RSUP Trial 2.

(a) Means per combination

	Ash		KCl		NaCl		50:50 KCl:NaCl	
Nutrient†	0.5	1	0.5	1	0.5	1	0.5	1
K	1.183	1.451	1.380	1.536	0.461	0.487	1.093	1.196
Na	0.172	0.202	0.087	0.060	0.343	0.442	0.254	0.255
Cl	0.587	0.716	0.704	0.841	0.692	0.709	0.780	0.901
SiO_2	0.225	0.300	0.079	0.075	0.092	0.079	0.072	0.063

(b) Means per main treatment

	Main treatment				
Nutrient†	Ash	KCl	NaCl	50:50 KCl:NaCl	*s.e.* main treatment
K	1.317	1.458	0.474	1.145	0.086
Na	0.187	0.074	0.393	0.255	0.023
Cl	0.652	0.773	0.701	0.841	0.030
SiO_2	0.263	0.077	0.086	0.068	0.022

(c) Means per subdivision

	Subdivision‡		
Nutrient†	0.5	1	*s.e.*subdivision
K	1.029	1.168	0.071
Na	0.214	0.240	0.012
Cl	0.691	0.792	0.014
SiO_2	0.117	0.129	0.013

†Nutrient contents in leaf 14 as a % of dry matter, at 36 months.
‡Subdivisions. 0.5: half rate; 1: full rate.
Two significant interactions exist between type of fertilizer and rate on Na and Cl nutrients, but without any agronomic meaning.

rate are growing better, flowered earlier and have better nut loads than those receiving the half rate. In other words, young hybrid coconuts planted on developed peat need complete mineral fertilizer to enter their mature phase under the best conditions.

There is no significant repeatable interaction between the main treatments and subdivisions in trial 2.

As shown in Table 7, there is excellent growth at $3^1/_2$ years for the coconut palms in the main treatments (ash and KCl) with a collar girth over 1.5 m and a frond length over 4.5 m, and the set-fruit load of the palms at $3^1/_2$ years is exceptionally good for ash and KCl at the full rate.

Be it for vegetative growth, early flowering or first nut sets, the coconut palms fertilized with coconut husk ash are always in the leading group. This proves the very good potential of deep peat for coconut hybrids provided production factors are controlled, namely mineral nutrition for which coconut husk ash proves to be an excellent fertilizer.

DISCUSSION

The two field trials have shown that coconut husk ash is a very suitable fertilizer for peat soil. It is complete (except N, but there is very little need for it on developed peat) and notably contains a high percentage of K, which is the most sensitive nutrient on developed peat. In addition, the nutrients it contains are effectively taken up by coconut palms.

A mineral analysis showed to what extent coconut husk ash reflects the nutritional status of the palms from which it comes. In a fertilization trial involving mature PB 121 coconut hybrid palms comparing various combinations of KCl and NaCl, we analysed the mineral composition of husk ash per treatment (unpublished data) . The analysis showed that the K content of coconut husk ash clearly reflects the amount of K fertilizer applied in the past, varying from 20 to 24% (for the control palms or those fertilized solely with NaCl) up to 36% (for palms fertilized solely with high rates of KCl).

It is important to note that the K content of husk ash from K-deficient palms is far from negligible. Coconut husk ash therefore proves to be an effective K concentrator and its ash consequently has a virtually guaranteed minimum K rate, whatever the nutritional status of the palms from which it comes. This perfectly natural fertilizer is easy to produce locally, by simply incinerating the fresh product and recovering the ash. It is cheap per unit of K when compared to imported fertilizers, especially since the price of the latter has risen.

One possible limitation when using this by-product on an agro-industrial scale is that burning husks produces smoke. It has been found that smoke emissions into the atmosphere remain very limited if small heaps are burnt in the field (Bonneau *et al.* 2007). Moreover, satellite hot spot records show that no hot spots were detected in the RSUP estate in July and August 2008, unlike the situation over the same period in neighbouring districts of the same province, Riau, where multiple bushfires are regularly detected in the dry season. It is now necessary to check smoke emissions from large incinerators.

In fact, several ways of using coconut husk ash can be envisaged on an agro-industrial scale.

The first and simplest solution consists in burning coconut husks in the field at the foot of the coconut palms, and allowing the ash to act as a fertilizer. The main reason for this practice is phytosanitary, to control the pest *Sufetula* (Bonneau *et al.* 2007), and the palms benefit in the process from partial recycling of nutrients, including K. The drawback is that recycling is not calibrated. The amount of husk ash received per coconut palm is not regular in either space or time.

A second solution would be to stockpile husks near incinerators, produce ash, bag the product and then redistribute it to the coconut palms, exactly like fertilizer, spreading it in the weeded circle around the stem. The advantage would be that husk ash would be distributed according to the actual needs of the coconut palms. However, transporting husks to the incinerator, burning them, recovering the ash and bagging it, then transporting bags back to the foot of the coconut palms and spreading the ash carries a cost. The method is therefore going to be tested in a pilot plot in which an incinerator is to be built.

A third solution would consist in producing husk ash from coconut palms at the end of their cycle (for one or two years before their programmed felling), storing it in fertilizer warehouses spread throughout the plantation, and then using it as fertilizer on young coconut palms in replantings, precisely as was done in trials 1 and 2.

Once again it should be remembered that, in each case, coconut husk ash is by definition a supplemental fertilizer and that imported K fertilizer cannot be done away with completely. Even though coconut husk concentrates a high proportion of the K contained in the whole coconut palm (Ouvrier *et al.* 1978), it is still the case that it can only recycle what it contains, i.e. only a proportion of total exports and immobilizations. In other words, using coconut husk ash to fertilize coconut palms in a closed circuit is an excellent way of making savings on imported K fertilizer, but it is not a total substitute.

CONCLUSION

Coconut husk ash proves to be a very efficient fertilizer for coconut palms grown on an organic medium such as deep peat. In particular, it provides two essential nutrients for coconut, K and Cl. In that respect, it can be used to replace KCl in a proportion of two and a half to one. It is therefore an excellent supplemental fertilizer which effectively recycles a fair share of the nutrients concentrated in husk.

The best conditions for using this by-product from coconut estates remain to be determined. Organizing mass production depends on technical feasibility, the minimization of production costs and optimization of by-product distribution. In spatial terms, should the operation be on a plot scale with direct redistribution, or on an estate scale with storage warehouses? In terms of timing, should there be immediate redistribution to mature coconut palms or storage in warehouses for deferred use on immature palms in replantings?

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