

Effects of increasing rates of sodium chloride (common salt) fertilization on coconut palms grown under an inland soil (Tropudalfs), of Mindanao, Philippines

S. S. MAGAT, R. Z. MARGATE and J. A. HABANA (1)

Summary. — The influence of increasing rates of NaCl (common salt) : 0, 0.88, 1.76, 3.52 and 7.04 kg/tree/year, corresponding to 0, 0.48, 0.97, 1.94 and 3.87 kg Cl/tree/year, respectively, was studied on local tall « Laguna » coconuts grown on the Cl-deficient Tugbok soil (Typic Tropudalfs). In general, NaCl applications increase nut production, copra weight/nut and copra yield/tree, but not oil content (p. 100). For equal Cl rates, yield data are very similar to those obtained with KCl fertilization. Leaf-N (p. 100) is positively related to and the main determinant of nut production, while leaf-Cl (p. 100) the one positively related to and main determinant of copra per nut and copra yield. The positive response to KCl applications observed in earlier studies [Magat *et al.*, 1975 ; Margate *et al.*, 1979 ; Magat *et al.*, 1981] is due to the Cl component of the fertilizer, as suggested in the above studies. NaCl may be used to replace KCl, which is an expensive fertilizer : in this study, the optimum economic NaCl rate was 3.8 kg/tree/year (yielding 25.9 kg copra, ie + 112 p. 100), although the rate of 1 kg/tree/year already made it possible to obtain more than half of the positive effects corresponding to the optimum economic rate.

INTRODUCTION

In earlier studies by the Philippine Coconut Authority (PCA), the application of KCl (50 p. 100 K, 44 p. 100 Cl) corrected the chlorine deficiency of coconuts, resulting in substantial increases in nuts and copra [Mendoza and Prudente, 1972 ; Magat *et al.*, 1975 ; Margate *et al.*, 1979 ; Magat *et al.*, 1981]. In two of these studies, p. 100 leaf-Cl (leaf N° 14) and not p. 100 leaf-K was positively correlated with copra per nut, suggesting that the positive response to KCl application was probably due to the Cl component of the said fertilizer.

In this light, the use of NaCl (common salt) containing 55 p. 100 Cl, whose suitability as a Cl source for coconuts has been indicated by earlier works [Magat *et al.*, 1978 ; Palomar and Magat, 1980 ; Magat and Padrones, 1981], was studied instead of KCl. The optimum economic rate for bearing palms and the influence of different NaCl rates on leaf nutrient concentration (N, P, K, Ca, Mg, Cl, S and Na) had not yet been closely evaluated. This paper presents the results obtained over a five year period of regular NaCl applications on Cl-deficient palms previously receiving KCl fertilizer at the Davao Research Center, PCA.

MATERIALS AND METHODS

Environmental conditions.

The details of the location, climate and soil conditions at the experimental site have already been reported [Magat *et al.*, 1975, Magat and Padrones, 1981]. Located about 11 km (inland), from the coast, the area is 120-160 m above sea level, with a deep and well-drained soil classified as Typic Tropudalfs [Labarcon, 1980]. On average, the

soil has 0.81 meq K and 0.11 meq Na/100 g soil, and 70 p. 100 base saturation.

Experimental palms.

« Laguna » talls (30 year old) planted in an 8 m × 8 m square were used as experimental trees. These were the same trees used earlier for the KCl rates study (1975-1980).

Fertilizer treatment.

Five rates of NaCl (0, 0.88, 1.76, 3.52 and 7.04 kg/tree/yr) with corresponding Cl rates (0, 0.48, 0.97, 1.94, 3.87 kg/tree, respectively), were used. The fertilizer treatment were applied in split applications at six months interval by broadcast and incorporation method, within the 1.5-2.0 m circle weeded area of the palms.

In addition, all palms received a blanket application of 2.0 kg (NH₄)₂SO₄/tree/yr.

Experimental design.

The study was laid out in a Randomized Complete Block (RCB) design with the five NaCl treatments replicated three times, consisting of nine palms per plot.

Harvesting and yield estimate.

Matured nuts were harvested every 45 days (8 times/year) at which 20 nuts/plot were sampled for copra weight/nut determination as basis of copra yield/tree (nuts/tree × copra/nut).

Sampling and analyses of leaf, and oil.

Leaf samples for nutrient content (p. 100) analysis (N, P, K, Ca, Mg, Na, Cl, S) at the Tissue Analysis Laboratory (TAL), PCA, were collected from each plot prior to initial NaCl application and annually thereafter, following the procedure of Magat and Froilan [1976].

For oil content, copra samples from the April 1985

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harvest were analyzed at the Breeding and Genetics Laboratory, Zamboanga Research Center. The oil content was determined by boiling the copra sample in a Soxhlet apparatus, with trichlorethylene solvent extraction for eight hours.

Statistical analyses.

The data (yield, leaf nutrient concentrations) were subjected to ANOVA, Correlation and Regression to determine the effects of treatments, and yield and independent variables relationships.

RESULTS AND DISCUSSIONS

Yield.

In general, the application of NaCl significantly increased nut production, copra weight/nut and copra yield/tree, but did not affect the oil content of bearing palms grown in the Tugbok clay loam soil, an inland Cl-deficient soil (Table I).

Yield data were adjusted to Mitscherlich curves (Figs. 1 and 2 — nut/tree, copra/nut and copra/tree — average of 5 years' harvest), with a level of significance at P = 0.05.

The relative increase in yield due to NaCl has a potential effect which is greater on copra per nut (+ 60 p. 100) than on nut per tree (+ 37 p. 100). Although adjustment methods were not the same, it is clear that given equal Cl rates, the coconut responses to NaCl applications are comparable to those obtained in earlier KCl fertilization studies [Margate *et al.*, 1979]. These results indicate that NaCl may be used to replace KCl.

The oil content of copra was not significantly affected by increasing rates of NaCl, with minus-NaCl and plus-NaCl palms having an average of 63.4 p. 100 and 63.8 p. 100 oil, respectively. This suggests that oil content of coconuts is very likely a function of factors other than palm nutrition, probably dependent on the genetics of the coconut.

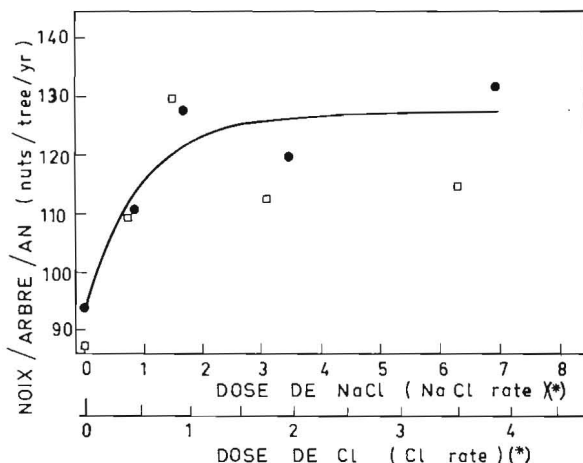


FIG. 1. — Relationship between NaCl application and number of nuts/tree/year (Relation entre les apports de NaCl et le nombre de noix/arbre/an) :

— • : average of 5 years' harvest (moyenne de 5 années de récoltes).
 — Y = 127.20 - 34.13 exp (- 1.05 x).

— Results obtained in the same trial point with former KCl applications (Résultats obtenus au même point d'essai avec les apports de KCl précédents).

For comparison (Pour comparaison)

— □ : average of 5 years' harvest (moyenne de 5 années de récoltes) [Margate *et al.*, 1979].

— Comparison made for equal Cl rates (Comparaison réalisée à dose de Cl égale).

(*) : kg/tree/year (/arbre/an).

Leaf nutrients.

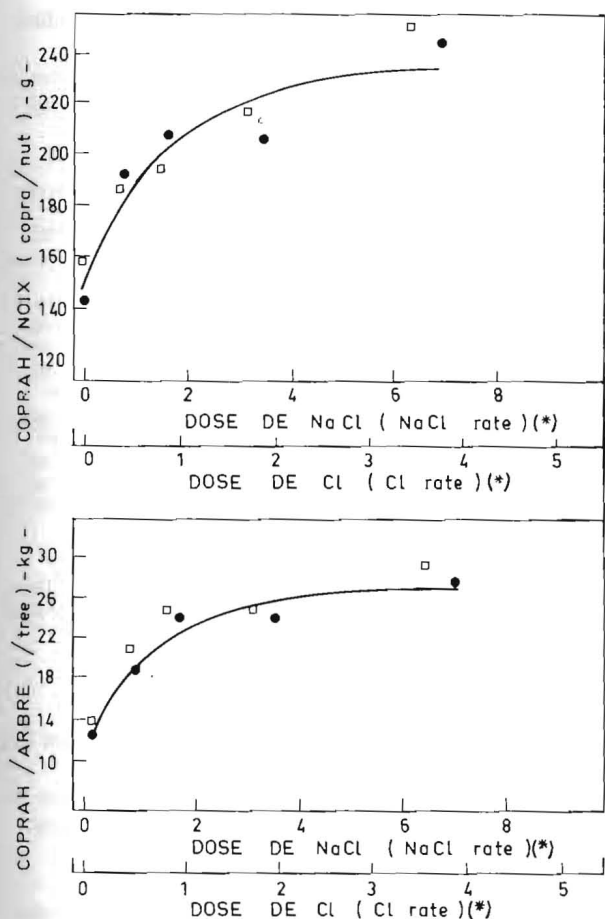
Of the leaf nutrients analyzed (N, P, K, Ca, Mg, Na, Cl, S and B) only leaf Na and Cl were significantly influenced by NaCl application (Table II). Leaf Na levels remained very low, perhaps due to good K levels, but Cl levels increased parabolically (Fig. 3). The application of 1.76 kg NaCl (0.97 kg Cl)/tree/yr made it possible to reach the optimum level (0.5 p. 100) suggested by Ollagnier *et al.* [1971] and 0.5 — 0.60 p. 100 as reported by Magat *et al.* [1986]. Based on the p. 100 leaf-Cl level of 0.30 p. 100 reported by the same authors, the control palms in the current work are highly deficient in Cl.

TABLE I. — Effects of increasing NaCl rates on nut production, copra weight per nut, copra yield per tree and oil content (5-year average)

(Effets des doses croissantes de NaCl sur le rendement en noix, le coprah/noix, le coprah/arbre et la teneur en huile — moyenne de 5 ans)

NaCl rate (1) (Dose de NaCl) kg/tree/yr (/arbre/an)	No Nuts/tree (Nbre de noix/arbre)	Copra/nut (Coprah/noix) (g)	Copra/tree (Coprah/arbre) (kg)	Oil content (Teneur en huile) (p. 100)
0	93.5	143.2	12.2	63.4
0.88	110.6	192.5	18.8	63.2
1.76	127.7	207.3	24.0	64.6
3.52	119.5	207.8	23.9	64.4
7.04	130.7	244.4	27.6	63.1
Statistical significance (Signification stat.)	**	**	**	NS
HSD (Différence significative à)				
P = 0,01	15.9	45.6	6.7	—
C.V. p. 100	3.8	6.4	8.4	6.0

NS : Not significant (Non significatif) ; ** : Highly significant — 1 p. 100 level (Hautelement significatif à P = 0,01).
 (1) : Blanket application of 2 kg (NH₄)₂SO₄/tree/yr (Apport uniforme de 2 kg de (NH₄)₂SO₄/arbre/an).



(*) : kg/tree/year (/arbre/an).

FIG. 2. — Relationship between NaCl applications and copra yield (Relation entre les apports de NaCl et la production de coprah) :
 — • : average of 5 years' harvest (moyenne de 5 années de récoltes).
 — Copra/nut (Coprah/noix) : $\bar{Y} = 236.25 - 88.58 \exp(-0.58 x)$.
 — Copra/tree (Coprah/arbre) : $\bar{Y} = 26.76 - 14.54 \exp(-0.73 x)$.
 — Results obtained in the same trial point with former KCl applications (Résultats obtenus au même point d'essai avec les apports de KCl précédents).

For comparison (Pour comparaison) — □ : average of 5 years' harvest (moyenne de 5 années de récoltes) [Margate et al., 1979].
 — Comparison made for equal Cl rates (Comparaison réalisée à dose de Cl égale).

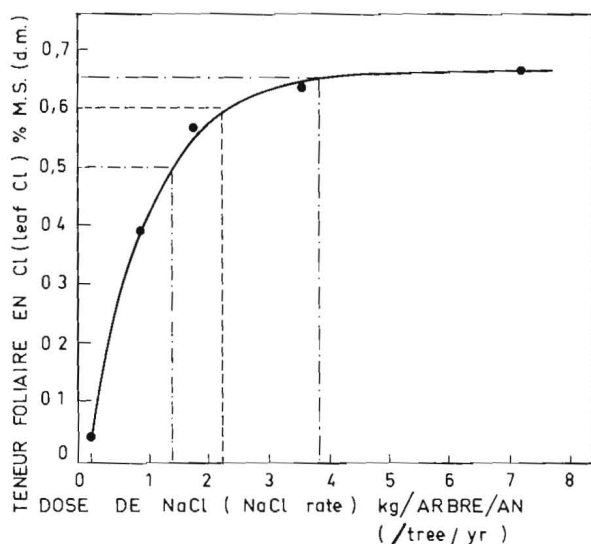


FIG. 3. — Relationship between NaCl applications (kg/tree/yr) and 1984 leaf-Cl concentration (p. 100 dm) (Relation entre les apports de NaCl — kg/arbre/an — et la teneur foliaire en Cl en 1984 — p. 100 ms).
 $\bar{Y} = 0.676 - 0.637 \exp(-0.947 x)$.

TABLE II. — Leaf nutrient levels of coconuts as affected by NaCl fertilization (1)
 (Teneurs foliaires en éléments nutritifs en fonction des doses de NaCl)

NaCl fertilizer rate (Dose de NaCl) (kg/tree/yr-/arbre/an)	Leaf nutrient (Eléments nutritifs) — p. 100 dry matter (matière sèche)								
	N	P	K	Ca	Mg	Na	Cl	S	B (ppm)
0	1.76	0.124	1.27	0.36	0.20	0.054 ^{b(2)}	0.04 ^d	0.182	8.0
0.88	1.87	0.129	1.15	0.35	0.19	0.071 ^a	0.39 ^c	0.174	7.7
1.76	1.91	0.127	1.09	0.37	0.18	0.056 ^b	0.57 ^{bc}	0.173	7.4
3.52	1.89	0.129	1.31	0.34	0.17	0.056 ^b	0.64 ^{ab}	0.168	7.4
7.04	1.87	0.128	1.17	0.39	0.19	0.069 ^a	0.68 ^a	0.177	7.3
Statistical significance (Signification statistique)	NS	NS	NS	NS	NS	*	**	NS	NS
Standard error (Ecart-type)	0.03	0.003	0.05	0.02	0.013	0.004	0.04	0.005	0.22
C.V. (p. 100)	3.6	4.7	8.2	10.2	11.5	10.2	16.2	4.9	5.1

(1) Sampled December 1984, leaf N° 14 (Prélèvement de décembre 1984, feuille de rang 14).

(2) Means having the same letter(s) under each column are not significantly different at 5 p. 100 level (Dans chaque colonne les moyennes accompagnées de la même lettre ne diffèrent pas significativement à P = 0,05).

NS : Not significant (Non significatif) ; (*) : Significant (Significatif à) P = 0,05 ; (**) : Highly significant (Hautelement significatif à) P = 0,01.

Correlation and regression analyses.

The correlation analysis of yield parameters and leaf nutrient concentrations showed that only leaf-N and Cl were positively related with nut/tree, leaf-Cl with copra/nut and leaf-N and Cl with copra/tree (Table III). On the other hand, leaf-Mg proved to be negatively correlated with nut/tree and copra/tree, which is surprising because Mg levels were rather low. Nevertheless, as step-wise regression analysis indicated that for nut production, leaf N was the main yield determinant, while for both copra weight/nut and copra yield/tree, leaf-Cl concentration was the main yield determinant (Table IV).

These results indicate that the yield improvement in terms of copra was due to the corrective influence of NaCl on Cl deficiency. Several authors reported positive correlation of leaf-Cl p. 100 and copra yield. [Ollagnier and Ochs, 1971 ; Uexkull, 1972 ; Prudente and Mendoza, 1976]. Also, in fodder beet (*Beta vulgaris*) a NaCl-responsive crop, Magat [1985] found that leaf-Cl concentration was positively correlated with high sugar yields (fresh roots \times p. 100 sucrose-sugar).

In other respects, the blanket application of $(\text{NH}_4)_2\text{SO}_4$ corrected the apparent N deficiency, which resulted in increased nut production.

High nut/tree and high copra/nut eventually produces high copra/tree/yr as this is the product of nut/tree/yr and copra/nut. Furthermore, copra yield per hectare depends not only on copra/tree but on number palms/ha, thus the need for proper nutrition and optimum planting density in obtaining high productivity.

Economics of NaCl fertilization.

The optimum economic rate corresponds to the point from which any additional fertilizer application is not more than compensated for by a corresponding increase in production. It can be calculated using the following formula :

$$\frac{dy}{dx} \cdot \frac{Py}{Px} = 1$$

where :

- $y = 26.76 - 14.54 \exp(-0.73 x)$,
(kg copra/tree) (kg NaCl/tree)

- $\frac{dy}{dx}$: derivative of the production function compared to x ;

- Py : copra selling price (3.00 pesos/kg) (1) ;
- Px : price per kg of NaCl (2.00 pesos/kg) ;

hence : $x = 3.8$ kg of NaCl/tree/year (i.e. 2.1 kg of Cl).

This optimum economic rate, under the conditions of the experiment, gives nuts/tree of 126 (+ 36 p. 100), copra/nut of 226 g (+ 53 p. 100) and copra/tree of 25.9 kg (+ 112 p. 100). The corresponding leaf-Cl concentration (0.66 p. 100) proves to be higher than the optimum level (0.50 p. 100) suggested by Ollagnier *et al.* [1971] and (0.5 - 0.60 p. 100) by Magat *et al.* [1986].

Even when it is decided to ration fertilizers, it can be seen that already over half the increase (55 p. 100) in copra/tree observed with the optimum economic rate is obtained with only 1 kg of NaCl/tree/yr (19.8 kg/tree/year, i.e. + 62 p. 100/C).

TABLE III. — Linear correlations (r) of yield indices and leaf nutrient concentrations.

(Corrélations linéaires — r — entre les composantes rendement et les teneurs foliaires en éléments nutritifs)

Nutrient (Elément nutritif)	Yield indices (Composantes du rendement)		
	Nuts/tree (Noix/arbre)	Copra/nut (Coprah/noix)	Copra/tree (Coprah/arbre)
N	0.86**	0.44 NS	0.72**
P	-0.04 NS	0.06 NS	-0.04 NS
K	0.13 NS	-0.10 NS	-0.05 NS
Ca	-0.20 NS	0.21 NS	-0.04 NS
Mg	-0.74 **	0.01 NS	-0.54*
Na	-0.33 NS	0.43 NS	0.02 NS
Cl	0.58*	0.85**	0.80**
S	0.11 NS	-0.11 NS	-0.02 NS
B	0.24 NS	-0.23 NS	0.05 NS

Tabular r -values { r (df - dl - 13,5 p. 100) = 0.51,
(Seuil significatif) r (df - dl - 13,1 p. 100) = 0.64.
NS : Not significant (Non significatif) ; (*) : Significant (Significatif à) $P = 0,05$; (**) : Highly significant at (Hautement significatif à) $P = 0,01$.

TABLE IV. — Stepwise regression analysis on yield and leaf nutrients level (x 's)

(Régression pas à pas des composantes du rendement et rapport aux teneurs foliaires en éléments nutritifs)

	B-coefficient	R-squared (R carré)	F-value (Valeur de F)
Nuts per tree (\bar{Y}_1 in No.) (Noix/arbre - \bar{Y}_1 en nombre)			
Model	—	0.879**	43.79*
Intercept	-185.235	—	—
N	222.775	0.740	32.68*
Mg	-470.552	0.139	13.88*
Copra per nut (\bar{Y}_2 in g) (Coprah/noix - \bar{Y}_2 en g)			
Model	—	0.909**	36.86*
Intercept	-213.037	—	—
Cl	139.157	0.731	35.40*
S	1.658.184	0.128	11.01*
Na	660.620	0.049	6.03*
Copra per tree (\bar{Y}_3 in kg) (Coprah/arbre - \bar{Y}_3 en kg)			
Model	—	0.919**	41.77*
Intercept	-43.142	—	—
Cl	32.534	0.655	84.58*
S	405.596	0.191	21.04*
Mg	-87.034	0.072	9.91*

(*) : Significant at (Significatif à) $P = 0,05$; (**) : Highly significant at (Hautement significatif à) $P = 0,01$.

Sodium chloride is of even greater interest in that it is available locally and the cost of potassium chloride, which is imported, is prohibitive (4,00 pesos/kg) and continues to increase : at the present time, Cl, costs 9,1 pesos per kg with KCl against 3,6 pesos/kg with NaCl.

The optimum economic rate of 3.8 kg of NaCl/tree/year is therefore a good initial reference for considering copra nut fertilization in regions deficient in chlorine.

(1) US \$ 1 = 20 pesos in 1987.

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RÉSUMÉ

Effets de doses croissantes de chlorure de sodium (sel ordinaire) sur des cocotiers plantés dans une zone intérieure à Mindanao, Philippines, sur un sol de type « Tropudalfs ».

S. S. MAGAT, R. Z. MARGATE et J. A. HABANA, *Oléagineux*, 1988, **43**, N° 1, p. 13-19.

Des doses croissantes de NaCl (sel ordinaire) : 0 ; 0,88 ; 1,76 ; 3,52 et 7,04 kg/arbre/an, correspondant respectivement à 0 ; 0,48 ; 0,97 ; 1,94 et 3,87 kg Cl/arbre/an, ont été testées sur des cocotiers Grands locaux de type « Laguna » cultivés sur le sol de Tugbok (« Typic Tropudalfs »), pauvre en Cl. En général, les apports de NaCl augmentent le rendement en noix, le coprah/noix et la production de coprah par arbre, mais n'influencent pas la teneur en huile (p. 100). Pour une même dose de chlore, les composantes du rendement sont très comparables à celles obtenues avec les apports de KCl. La teneur foliaire en N (p. 100) est liée de manière positive au rendement en noix, dont elle est le déterminant principal, alors que ce rôle est tenu par la teneur foliaire en Cl (p. 100) pour le coprah/noix et le coprah/arbre. Les réponses positives aux apports de KCl observées au cours d'études antérieures [Magat *et al.*, 1975 ; Margate *et al.*, 1979 ; Magat *et al.*, 1981] sont dues au composant Cl de l'engrais, ainsi que l'avaient suggéré ces auteurs. Le NaCl peut être utilisé pour remplacer le KCl qui est un engrais coûteux : dans cette étude, la dose optimale économique de NaCl est de 3,8 kg/arbre/an (pour un rendement de 25,9 kg de coprah, soit + 112 p. 100), bien que la dose de 1 kg/arbre/an permette déjà d'obtenir plus de la moitié des effets bénéfiques correspondant à la dose optimale économique.

RESUMEN

Efectos de unas dosis crecientes de cloruro de sodio (sal común) en cocoteros sembrados en una zona del interior, en Mindanao, Filipinas, en un suelo de tipo « Tropudalfs ».

S. S. MAGAT, R. Z. MARGATE y J. A. HABANA, *Oléagineux*, 1988, **43**, N° 1, p. 13-19.

Unas dosis crecientes de NaCl (sal común) de 0 ; 0,88 ; 1,76 ; 3,52 y 7,04 kg/árbol/año, representando respectivamente 0 ; 0,48 ; 0,97 ; 1,94 y 3,87 kg de Cl/árbol/año, han sido probadas en cocoteros Grandes locales de tipo « Laguna » cultivados en un suelo de Tugbok (« Typic Tropudalfs »), de contenido de Cl bajo. Los aportes de NaCl incrementan el rendimiento de nueces por lo general, como también la copra/nuez y la producción de copra/árbol, pero no influyen en el contenido de aceite (p. 100). Considerándose una misma dosis de cloro, los componentes del rendimiento son muy comparables con los que proporcionan los aportes de KCl. El contenido de N (p. 100) en las hojas muestra una relación positiva con el rendimiento de nueces, siendo su determinante principal, cuando este papel lo desempeña el contenido de Cl (p. 100) en las hojas para la copra/nuez y la copra/árbol. Las respuestas positivas a los aportes de KCl anotadas en unos estudios anteriores [Magat *et al.*, 1975 ; Margate *et al.*, 1979 ; Magat *et al.*, 1981] se deben al componente Cl del fertilizante, según habían sugerido estos autores. NaCl puede emplearse para sustituir el KCl que es un fertilizante costoso : en este estudio, la dosis óptima económica de NaCl es de 3,8 kg/árbol/año (siendo el rendimiento de 25,9 kg de copra, o sea + 112 p. 100), aunque la dosis de 1 kg/árbol/año permita ya obtener más de la mitad de los efectos benéficos que corresponden a la dosis óptima económica.