# AN ESTIMATION OF THE CRITICAL AND OPTIMUM LEVELS OF LEAF-CHLORINE IN BEARING COCONUTS: A GUIDE FOR FOLIAR DIAGNOSIS

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**The critical and optimum concentrations of leaf-Cl in bearing coconuts (*Laguna* tall variety grown on Cl-deficient inland Tropudalf soil of Davao (Mindanao, Philippines) were analyzed using a factorial $3^3$(N, K, Mg) plus or minus Cl with incomplete block design consisting of 54 subplots (12 trees/plot).**

**The analyses consisted of relating yield and leaf nutrient concentrations of leaf 14, and applying a general linear model approach, correlation, multiple regression, curve-fitting (particularly quadratic trend analysis). The optimum leaf-Cl levels found for the yield indices were as follows: nut/tree = 0.51%; copra/nut = 0.63%; and, copra/tree = 0.56%. The leaf-Cl of 0.55% (leaf 14) may be used as an average optimum level reference for bearing coconuts. The critical leaf-Cl level for both nut production and copra yield was found to be 0.30%. These values may be used as a guide in the foliar diagnosis of coconuts.**

## INTRODUCTION

Chlorine (Cl) is strongly considered by some authors as a macronutrient for two important tropical vegetable oil-bearing crops - oil palm and coconuts (Ollagnier and Ochs 1971; Von Uexkull 1972; Mendoza and Prudente 1972; Magat et al. 1975; Manciot et al. 1979). Their findings correlate leaf-Cl, not leaf-K, with yield, particularly in soils with adequate supply of potassium (K) ($\geq$0.40 m.e./100 g soil).

The Cl application on oil palm either in the form of potassium, chloride (KCl), or sodium chloride (NaCl) improved the yield appreciably, accompanied by increased leaf-Cl, but not leaf-K, indicating that Cl deficiency exists and the yield is positively correlated with leaf-Cl (Ollagnier and Ochs 1971). In Papua, New Guinea, a similar finding has been reported by Breure and Rosenquist (1976).

Studies on coconut in the Philippines demonstrated clearly the positive need for Cl. Prudente and Mendoza (1976) found that application of KCl significantly increased yield, accompanied by a marked increase in leaf-Cl, but not in leaf-K. In a separate but related work, the KCl application (0-3.33 kg/tree/yr) increased significantly all yield indices (nut/tree, copra/nut, copra/tree) (Magat et al. 1975). An analysis of the nutrient contents revealed that among the nutrients, only leaf-Cl was affected by KCl application with an apparent linear response to increasing rates of fertilization.

In Sri Lanka, Loganathan and Balakrishnamurti (1979) found that leaf-K and leaf-Cl contents were increased by KCl application, and yields were positively correlated with these leaf nutrients. Moreover, in North Sumatra (Indonesia), the positive response in growth and yield of the high-yielding coconut hybrids (MAWA-Port Bouet 121) was attributed to either K or Cl (Rosenquist 1980). It therefore appears that chlorine deficiency of coconut areas could be world-wide.

Among the diagnostic tools, Foliar Diagnosis is found to be a rapid and acceptable technique to deter-

| Treatment | Wt of Nutrient | Wt of Fertilizer | Source[1] |
|---|---|---|---|
| $N_0$ | 0 g N | 0 g AC | 0 g AS |
| $N_1$ | 140 g N | 600 g AC | 700 g AS |
| $N_2$ | 280 g N | 1200 g AC | 1400 g AS |
| $K_0$ | 0 g K | 0 g KC | 0 g KS |
| $K_1$ | 425 g K | 850 g KC | 1000 g KS |
| $K_2$ | 850 g K | 1700 g KC | 2000 g KS |
| $Mg_0$ | 0 g Mg | 0 g Dol | |
| $Mg_1$ | 48 g Mg | 400 g Dol | |
| $Mg_2$ | 96 g Mg | 800 g Dol | |

[1]AC = $NH_4Cl$ (25% N, 55% Cl)
AS = $(NH_4)_2SO_4$ (20% N, 24% S)
KC = KCl (50% K, 44% Cl)
KS = $K_2SO_4$ (41% K, 18% S)
Dol = $CaMgCO_3$ (12% Mg, 28% Ca)

**TABLE 1.** Fertilizer treatments and rates (per palm/yr), 1980-1986. (Coconut chlorine nutrition from nursery to full-bearing)

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mine nutritional status and predict the fertilizer needs (Magat 1978 and Manciot et al. 1979). However, it requires a proper guide on the critical and optimum leaf-Cl. In this regard, some useful results on the determination of the critical levels of leaf-Cl, based from a long-term Cl nutrition work (factorial) on local tall coconuts started in 1974 in Davao (Mindanao, Philippines), are presented in this paper.

## MATERIALS AND METHODS

The study used the yield data and leaf nutrient analyses, particularly on leaf-Cl concentrations (leaf 14), of long-term test of the Davao Research Center on Cl nutrition of coconuts, from the polybag nursery to full-bearing stage. The coconuts were local talls, *Laguna*, field-planted in August 1975. The fertilizer treatments involved a $3^3$ factorial (N, K, Mg), plus or minus Cl in split-plot with incomplete block design, with a total of 54 subplots at 12 trees per subplot. The palms were field-planted at 9 m x 9 m triangular system on a Cl-deficient inland-upland Tugbok clay loam (Magat et al. 1979) classified as Typic Tropudalfs (Labarcon 1980).

The rates of nutrients and corresponding fertilizer sources are shown in Table 1.

The latest eight harvests (in year 1985) were used as basis of nut production, and estimates of copra weight (g/nut) and copra yield (kg/tree) (Table 2). The concentrations of leaf nutrients during the year were considered in the study to relate nutrition with yield.

| Fertilizer Treatment | Nut/Tree (no.) | Copra/Nut (g) | Copra/Tree (kg) |
|---|---|---|---|
| Nitrogen (N) | | | |
| $N_0$ | 71.4 | 242.6 | 19.16 |
| $N_1$ | 72.5 | 258.5 | 20.37 |
| $N_2$ | 79.8* | 267.3* | 22.86* |
| Potassium (K) | | | |
| $K_0$ | 68.4 | 246.0 | 18.59 |
| $K_1$ | 77.0* | 257.3 | 21.68* |
| $K_2$ | 78.3* | 265.2* | 22.12 |
| Magnesium (Mg) | | | |
| $Mg_0$ | 73.8 | 245.3 | 20.00 |
| $Mg_1$ | 72.4 | 262.1 | 20.50 |
| $Mg_2$ | 77.5 | 261.0 | 21.89 |
| Chlorine (Cl) | | | |
| - Cl | 63.4 | 222.8 | 15.39 |
| + Cl | 85.7** | 289.5** | 26.30* |
| Grand mean | 74.6 | 256.1 | 20.80 |
| LSD - values: | | | |
| N or K or Mg means | | | |
| 5% | 8.1 | 17.6 | 2.60 |
| Cl means | | | |
| 5% | 5.8 | 11.6 | 2.09 |
| 1% | 8.0 | 16.1 | 2.87 |

*Significant at 5% level.
**Highly significant at 1% level

**TABLE 2.** **Effects of N, K, Mg, and Cl fertilizer treatments on yield of coconut (harvest period 1985)**

## RESULTS AND DISCUSSION

### Correlation and Regression Analysis

The leaf-N and leaf-Cl were positively correlated ($p \leq 0.01$) with all yield indices, nut/tree, copra/

| Treatment | Nutrient (% dry matter) N | P | K | Ca | Mg | Na | Cl | S | B(ppm) |
|---|---|---|---|---|---|---|---|---|---|
| Nitrogen | | | | | | | | | |
| $N_0$ | 1.82 | 0.139 | 1.56 | 0.33 | 0.180 | 0.042 | 0.18 | 0.16 | 9.3 |
| $N_1$ | 1.85 | 0.138 | 1.55 | 0.34 | 0.179 | 0.039 | 0.23 | 0.17 | 9.4 |
| $N_2$ | 1.87 | 0.141 | 1.53 | 0.35 | 0.183 | 0.046 | 0.33 | 0.17 | 8.9 |
| Potassium | | | | | | | | | |
| $K_0$ | 1.81 | 0.137 | 1.54 | 0.34 | 0.184 | 0.044 | 0.17 | 0.16 | 9.1 |
| $K_1$ | 1.86 | 0.140 | 1.57 | 0.34 | 0.176 | 0.040 | 0.26 | 0.17 | 9.3 |
| $K_2$ | 1.87 | 0.140 | 1.53 | 0.32 | 0.181 | 0.044 | 0.29 | 0.17 | 9.1 |
| Magnesium | | | | | | | | | |
| $Mg_0$ | 1.89 | 0.143 | 1.55 | 0.36 | 0.183 | 0.045 | 0.26 | 0.17 | 9.0 |
| $Mg_1$ | 1.84 | 0.140 | 1.54 | 0.34 | 0.179 | 0.041 | 0.24 | 0.17 | 9.1 |
| $Mg_2$ | 1.80 | 0.135 | 1.55 | 0.32 | 0.179 | 0.041 | 0.22 | 0.16 | 9.2 |
| Chlorine | | | | | | | | | |
| +Cl | 1.90 | 0.140 | 1.55 | 0.34 | 0.179 | 0.042 | 0.42 | 0.25 | 8.8 |
| -Cl | 1.79 | 0.138 | 1.54 | 0.34 | 0.182 | 0.043 | 0.16 | 0.16 | 9.5 |

**TABLE 3.** **Effect of N, K, Mg, and Cl on the leaf nutrient levels, leaf rank 14 (1985 leaf sampling)**

| | N | P | K | Ca | Mg | Na | Cl | S | B |
|---|---|---|---|---|---|---|---|---|---|
| Nut/tree | 0.453** | 0.136ns | 0.064ns | -0.062ns | -0.125ns | 0.164ns | 0.769** | 0.276* | -0.518** |
| Copra/nut | 0.380** | 0.148ns | -0.010ns | -0.063ns | -0.038ns | 0.015ns | 0.822** | 0.224ns | -0.577** |
| Copra/tree | 0.436** | 0.163ns | 0.030ns | -0.066ns | -0.074ns | 0.092ns | 0.856** | 0.240ns | -0.598** |
| B | -0.393** | -0.058ns | 0.206ns | 0.140ns | 0.101ns | -0.184ns | -0.670** | -0.123ns | 1.000 |
| S | 0.429** | 0.017ns | -0.112ns | 0.286* | -0.288* | -0.110ns | 0.222ns | 1.000 | |
| Cl | 0.541** | 0.167ns | 0.129ns | 0.077ns | -0.110ns | 0.059ns | 1.000 | | |
| Na | -0.060ns | 0.191ns | -0.103ns | -0.307* | 0.128ns | 1.000 | | | |
| Mg | -0.091ns | 0.246ns | -0.108ns | 0.103ns | 1.000 | | | | |
| Ca | 0.279* | 0.268ns | 0.068ns | 1.000 | | | | | |
| K | -0.075ns | 0.292* | 1.000 | | | | | | |
| P | 0.230ns | 1.000 | | | | | | | |
| N | 1.000 | | | | | | | | |

[1] Tabular r - values: $r_{(.05, 52)} = 0.269$
$r_{(.01, 52)} = 0.348$

ns- Not significant.
*- Significant at 5% level.
**- Highly significant at 1% level.

**TABLE 4.** **Simple correlation coefficient (r) of yield indices and leaf nutrients[1]**

nut and copra/tree (Table 4). However, a stepwise multiple regression analysis showed that only leaf-Cl concentrations significantly explained the variations in the yields accounting for 59% on nut production, 68% on copra/nut, and 73% on copra yield/tree (Table 5).

| | Nut/Tree ($Y_1$) | Copra/Nut ($Y_2$) | Copra/Tree ($Y_3$) |
|---|---|---|---|
| Intercept | 60.89 | 217.61 | 14.37 |
| Leaf Cl-level(X) | 57.85 | 163.04 | 27.15 |
| Model | | | |
| R - Squared | 0.59** | 0.675** | 0.732** |
| F - Value | 75.19** | 107.99** | 142.03** |

**TABLE 5.** **Stepwise Regression Analysis of yield indices and leaf-Cl**

| | Nut/Tree ($\hat{Y}_1$) | Copra/Tree ($\hat{Y}_3$) |
|---|---|---|
| Intercept | 56.17 | 12.60 |
| Leaf Cl-level(X) | 138.20 | 57.41 |
| $X^2$ | -134.74 | -50.74 |
| Model | | |
| R - Squared | 0.639** | 0.770** |
| F - Value | 45.22** | 85.60** |

**Highly significant at 1% level.

**TABLE 6.** **General Linear Model (Quadratic Equation) of yield and leaf-Cl**

## Determination of Optimum Leaf-Cl (%)

Testing or fitting of leaf-Cl and yield were done by general linear model approach. Two quadratic equations were derived: (1) on nut/tree and (2) on copra/tree (Table 6). These relationships are graphically shown in Figures 1 and 2, with 64% of the variations in nut production and 77% for copra yield explained by the quadratic models.

The X and $X^2$ coefficients of the said quadratic equations, corresponding to b and c values of the equation below, were used to find the optimum level of leaf-Cl (X opt):

(1) $X\ opt = \frac{-b}{2c}$

With the b and c values for nut/tree and copra/tree (Table 6) in equation (1), the optimum level of Cl for the different yield indices was computed as follows:

(1a) Nut/tree: $X\ opt_1 = -138.28/2\ (-134.74)$
$= 0.51\%$ Cl

(1b) Copra/nut: $X\ opt_2 = -309.46/2\ (-245.56)$
$= 0.63\%$ Cl

(1c) Copra/tree: $X\ opt_3 = -57.41/2\ (-50.74)$
$= 0.56\%$ Cl

The above equations show the optimum leaf-Cl % ranges from 0.51 to 0.63%, depending on the yield parameters. On the average, 0.55% leaf-Cl may be

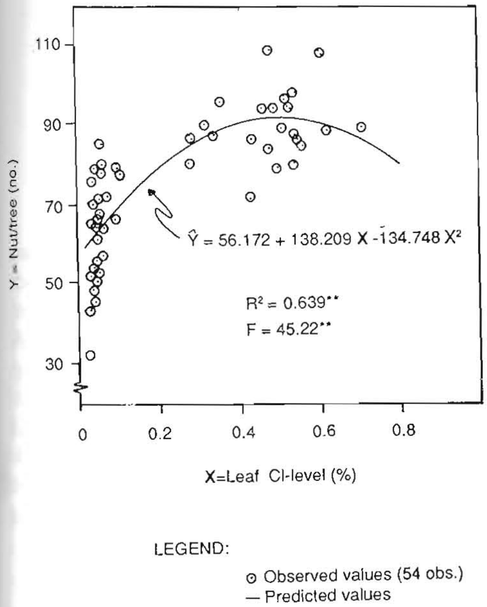


**Figure 1. Relationship between nut production per tree and Leaf Cl-level.**

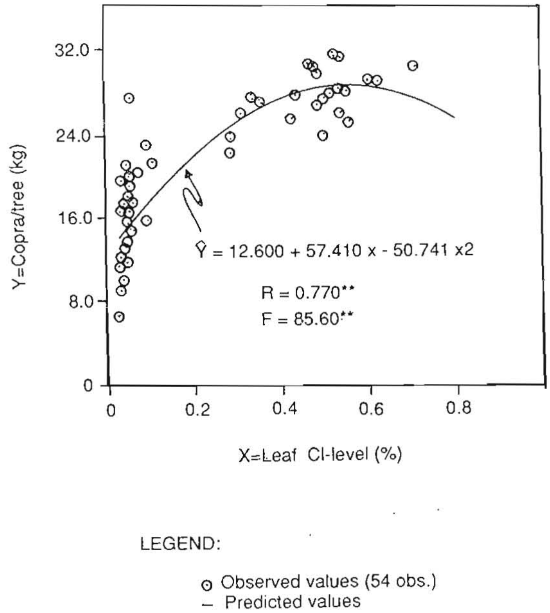


**Figure 2. Relationship between copra production per tree and leaf-Cl level.**

used as the optimum % Cl reference for local talls. In the absence of a similar study on dwarfs and hybrids, the values obtained in the current study can be taken as a guide in foliar diagnosis. It is interesting to note that the optimum Cl level of 0.50% suggested earlier by Ollagnier, Ochs, and Daniel (1976) is very near to the one found in the present work. Moreover, the present and the earlier reports support the stand of Manciot et al. (1979) that optimum levels of nutrients could be similar among tall varieties.

## Determination of Critical Leaf-Cl (%)

The critical level or threshold value of nutrient concentration refers to that level (% or ppm) of a leaf nutrient at a reference leaf of the palm which, when proper amount of the limiting nutrient is applied, will likely improve growth or yield significantly.

The quadratic equation:

(2) $Y = a + bx - cx^2$

was used to compute for the maximum yield at the optimum levels of leaf-Cl, where

<u>a</u> is the intercept
<u>b</u> is the slope or coefficient of <u>x</u>
<u>c</u> is the coefficient of <u>x²</u>
<u>x</u> is the optimum leaf-Cl

The maximum yields at a given optimum leaf-Cl were as follows:

(2a) Nut/tree: $\hat{Y}_{max-1} = 56.17 + 138.20\,(0.51) - 134.74\,(0.51)^2 = 91.6$ nuts

(2b) Copra/tree: $\hat{Y}_{max-2} = 12.60 + 57.41\,(0.56) - 50.74\,(0.56)^2 = 28.73$ kg

Under the conditions of the experiment, at 1% level of significance, a highly significant difference was detected with LSDs of 8 nuts/tree ($\hat{Y}_1$), and 2.87 kg copra/tree ($\hat{Y}_2$) (Table 2). Thus, for values of (3) $\hat{Y}_{max} - \hat{Y}$ for yield parameters, the computations were as follows:

(3a) $\hat{Y}_{max-1} - \hat{Y}_1 = 91.6 - 8 = 83.6$ nuts/tree

(3b) $\hat{Y}_{max-2} - \hat{Y}_3 = 28.73 - 2.87 = 25.86$ kg copra/tree

Hence, the leaf-Cl may be considered at a critical level when palms produce 83.6 nuts/tree and 25.86 kg copra/tree/yr. Consequently, these critical levels of leaf-Cl may be estimated by using equation 2. Based on the predicted values of yield ($\hat{Y}$) at different concentration (%) of leaf-Cl, the $\hat{Y}$s for nut production (85.5) and copra yield (25.3) closest to $\hat{Y}_{max-1} - \hat{Y}_1$ and $\hat{Y}_{max-2} - \hat{Y}_2$, respectively, corresponds to 0.30% leaf-Cl (Table 7).

| | Leaf Cl-level (X) | $\hat{Y}_1$ (no.) | $\Delta\hat{Y}_1$ | $\hat{Y}_2$ (kg) | $\Delta\hat{Y}_2$ |
|---|---|---|---|---|---|
| | 0.02 | 58 9 | 0 | 13.7 | 0 |
| | 0.05 | 62.8 | +3.1 | 15.3 | +1.6 |
| | 0 10 | 68.6 | +6.8 | 17.8 | +2.5 |
| | 0.15 | 73.9 | +5 3 | 20.1 | +2.3 |
| | 0.20 | 78.4 | +4 5 | 22.0 | +1.9 |
| | 0.25 | 82.3 | +3 9 | 23.8 | +1.8 |
| Critical level | 0 30 | 85.5 | +3.2 | 25.3 | +1.5 |
| | 0.35 | 88.0 | +2.5 | 26.5 | +1.2 |
| | 0.40 | 89.9 | +1.9 | 27.4 | +0.9 |
| | 0.45 | 91.1 | +1.2 | 28.2 | +0.8 |
| | 0.50 | 91.6 | +0 6 | 28.6 | +0.4 |
| | 0.55 | 91.4 | -0.2 | 28.8 | +0.2 |
| | 0.60 | 90.6 | -0.8 | 28.8 | 0 |
| | 0.65 | 89.1 | -1 5 | 28.5 | -0.3 |
| | 0.70 | 86.9 | -2.2 | 27.9 | -0.6 |
| | 0.75 | 84.0 | -2.9 | 27.1 | -0.7 |
| | 0.80 | 80.5 | -3.5 | 26.0 | -1.1 |
| | 0.85 | 76.3 | -4 2 | 24 7 | -1.3 |
| | 0.90 | 71.4 | -4.9 | 23.2 | -1.5 |

* $\hat{Y}_1$ (Nut/tree) = $56.172 + 138.209X - 134.748X^2$
$\hat{Y}_2$ (Copra/tree) = $12.600 + 57.410X - 50.741X^2$

**TABLE 7. Computed Predicted Values of yield (Y)* and slope (ΔY) with estimate of the critical level of leaf-Cl**

This study therefore establishes the critical level of leaf-Cl (leaf 14) for the local talls as 0.30%. The finding confirms the leaf critical value of 0.30% Cl of the West African Talls reported by Ollagnier, Ochs, and Daniel (1976). As in the optimum leaf-Cl level pointed out earlier in the paper, leaf-Cl critical levels for bearing talls in the Philippines, West Africa, and other coconut producing countries is likely similar. Moreover, the results of the present study suggest that the leaf-Cl level (0.50 - 0.60%), used as a reference in foliar diagnosis techniques in predicting fertilizer needs and in the mapping of nutritional deficiencies in coconut areas of the country (Magat et al. 1981), must be clearly understood as the optimum leaf-Cl (coconut yields very likely at maximum level already), and not the critical leaf-Cl (coconut yields limited by inadequate supply of Cl).

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