# Investigating the probable cause of crop decline in central Oahu

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## Summary

Extension agents brought forth concerns that a strange phenomenon was affecting multiple crop types in central Oahu. A multi-disciplinary team of specialists at the College of Tropical Agriculture and Human Resources (CTAHR) studied the incident called "Yellowing Problem" and ruled out disease and pesticide damage as the causal agent, leaving soil fertility as the most probable cause. Subsequently, a systematic investigation was conducted with six soil nutrient treatments: [1] control (receiving only a basal fertilizer as potassium nitrate, [2] iron sulfate (to counteract the high native soil manganese), [3] magnesium sulfate, [4] urea, [5] zinc sulfate, and [6] a combination of treatments [2], [3], and [5]. Chinese cabbage (pak choi) and chili pepper served as the test crops. Research indicates that nitrogen (N) was the cause of this decline as shown by the yellowing of lower leaves. Higher rates of ammonium producing fertilizers (e.g., urea, liquid ammonia, or ammonium sulfate) or organic N sources (e.g., compost, animal manure, meat meal) were strongly recommended for this particular area (soils with high percentage of iron and aluminum oxides and neutral pH), especially when rainfall is more than adequate.

## Introduction

Central Oahu is a relatively flat area situated between the two mountain ranges: Koolau on the east and Waianae on the west. This land area, which covers such towns as Waipahu in the south, Mililani and Wahiawa in the middle, and Waialua in the north is the primary vegetable production area in the Island. The soils of this area consist mainly of Oxisols at low elevations (e.g., Molokai and Wahiawa series) and Ultisols at higher elevations (e.g., Leilehua and Paaloa series) (Figure 1).

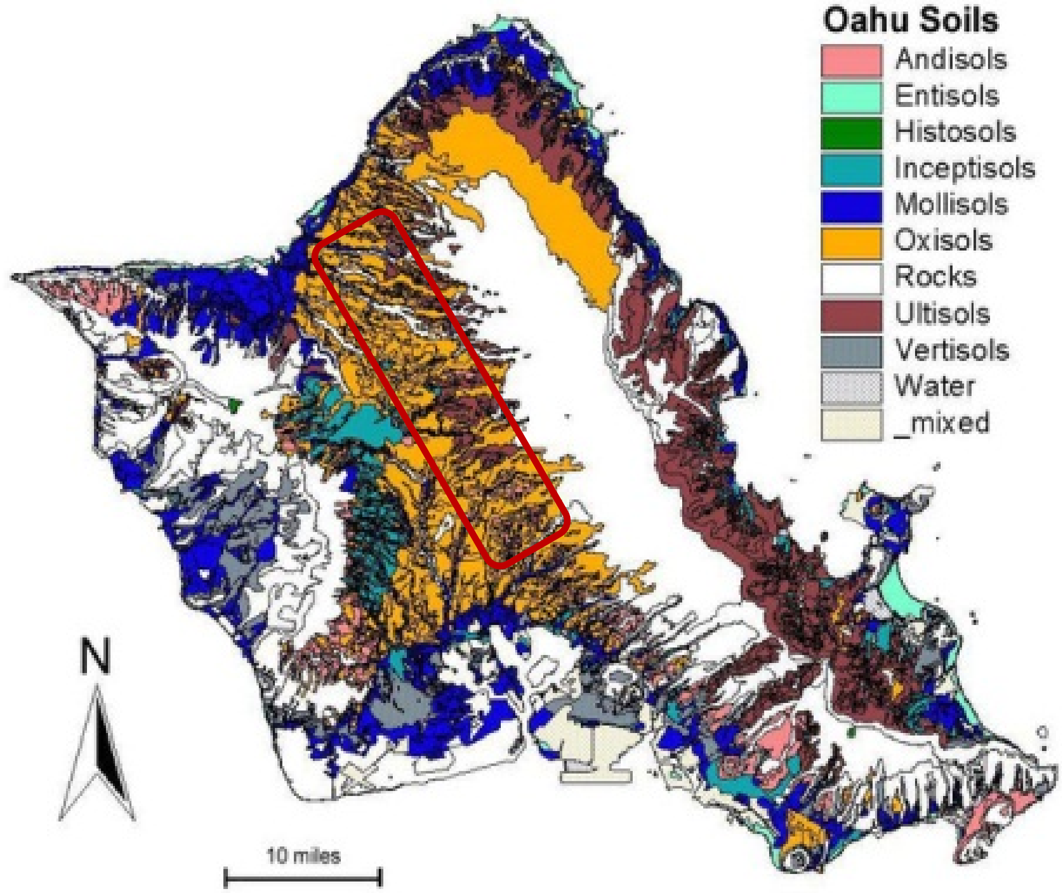


Figure 1. Soil orders in Oahu (Hue et al, 2006). The red box in the map indicates the area where the problem occurred.

The Oxisols in this area are known to contain rather high (5,000 – 10,000 mg/kg soil) of total manganese (Mn), which may cause Mn toxicity (if soil pH is acidic) or Mn-induced iron (Fe) deficiency (Hue et. al., 2001; Hue and Mai, 2002).

Recently, growers had noticed a crop yield decline called “Yellowing Problem” as shown in Figure 2. The yellowing of older leaves accompanied by reduced yield was first noted in the spring of 2006, and was initially attributed to the very wet weather immediately preceding. Yield improved after 18 months, but yellow leaf symptoms persisted. Recently symptoms have gotten worse, and yield declines have been observed. Although symptoms are consistent with nitrogen deficiency, low application rates (< 20 lb/acre of N) as calcium nitrate do not result in substantial yield increases.

Figure 2. Tomato plants with the yellowing symptom (right).

A collaborative effort by a multi-disciplinary team of specialists from the College of Tropical Agriculture and Human Resources (CTAHR) ruled out disease and pesticide damage , leaving soil fertility as the probable cause. As a first step, we evaluated the soil nutrient status of the “problem” area. The results from saturated paste extracts are shown below (Figure 3).

| sample | ID | pH | EC, dS/m | NH4-N | NO3-N | Ca | Mg | Mn | Zn | Cl |
|---|---|---|---|---|---|---|---|---|---|---|
| A | West 10-15cm | 6.98 | 0.44 | 1.1 | 3.0 | 12.6 | 6.8 | 0.08 | 0.015 | 32.2 |
| E | West 30-40 cm | 6.81 | 2.32 | 3.9 | 117.0 | 122.2 | 24.2 | 0.07 | 0.054 | 257 |
| B | South 10-15 cm | 6.35 | 2.02 | 1.9 | 280.0 | 165.0 | 33.1 | 0.57 | 0.057 | 101 |
| C | South 30-40 cm | 6.77 | 3.84 | 23.7 | 4.5 | 17.8 | 4.3 | 0.04 | 0.061 | 820 |
| D | East 10-15 cm | 7.00 | 1.21 | 2.3 | 38.0 | 57.5 | 13.3 | 0.03 | 0.031 | 88 |
| F | East 30-40 cm | 6.97 | 0.89 | 1.0 | 24.0 | 54.0 | 10.6 | 0.14 | 0.015 | 52 |
| | | | | | | | | | | |
| Saturated | | Paste | Extract | 8/31/2012 | | | | | | |
| All conc. | | are in mg/L | | | | | | | | |
| Wahiawa | | soils | Yellowing | problem | | | | | | |

Figure 3. Selected chemical composition in the saturated extract of soils from Wahiawa where the “Yellowing Problem” occurred.

Admittedly, the results were not as clear cut as we had hoped. Nitrogen ($NH_4$ and $NO_3$) were low in some areas, but high in the others. A similar distribution pattern was observed for Ca, probably as a result of $Ca(NO_3)_2$ applications. On the other hands, soil pH was near neutral, but Mg, Mn, and Zn seemed low in all the soil samples tested. Thus, we decided to systematically investigate the probable cause of this crop decline.

**Materials and methods**

Soils were collected from a “problem” field (Wahiawa Oxisol), air dried and screened through a quarter inch sieve. The soil was then treated with potassium nitrate ($KNO_3$) to provide 42 mg per kg N (approximately 85 lb/acre N) and 117 mg per kg K (We assumed that without N and K, crop would grow too poorly to reveal other deficiencies, if any). Then, five different fertilizer treatments were applied to the $KNO_3$ treated soil. These are (i) 112 mg/kg Fe as ferrous sulfate ($FeSO_4$) to counter-act high soil Mn, (ii) 48 mg/kg Mg as magnesium sulfate ($MgSO_4$) (iii) 10 mg/kg Zn as zinc sulfate ($ZnSO_4$) (iv) 70 mg/kg N as urea, and (v) 112 mg/kg Fe + 10 mg/kg Zn + 48 mg/kg Mg (combinations of treatments i, ii and iii, labeled as “combo” thereafter). The $KNO_3$-only added soil served as the control. One kg of treated soil was filled into a 6-inch plastic pot and incubated for 15 days before planting.

Pak choi cabbage (*Brassica rapa* Chinensis group) and chili pepper (*Capsicum frutescens* var. Waialua) seeds were sowed in seedling trays with a peat-based mix containing 20% vermicompost by volume. Two-week old seedlings were root washed and transplanted. The experiment was arranged in a randomized complete block design with four replications. Plants were harvested four weeks after transplanting. Plant fresh weight, dry weight and tissue N content were measured. Data from both experiments (with cabbage and chili pepper) were subjected to analysis of variance and mean separation using a statistical software package.

**Results**:

**Pak choi (Chinese cabbage)**. Average weights ranged from 12 - 31 grams (fresh) and 1.3 - 2.5 grams (dry) per plant. The plants treated with urea had the highest weights. Except for urea, none of the other treatments had significant effect on plant fresh and dry weights compared to the control (Figure 4). Correspondingly, leaf N concentration was highest (3.13%) in the urea treatment vs. 2.37% in the control and 1.92% (lowest) in the $MgSO_4$ treatment (Table 1). However, it is noted that pak choi plants regardless of treatments had N concentration below 3.5%, a level considered adequate according to Maynard & Hochmuth (2007).

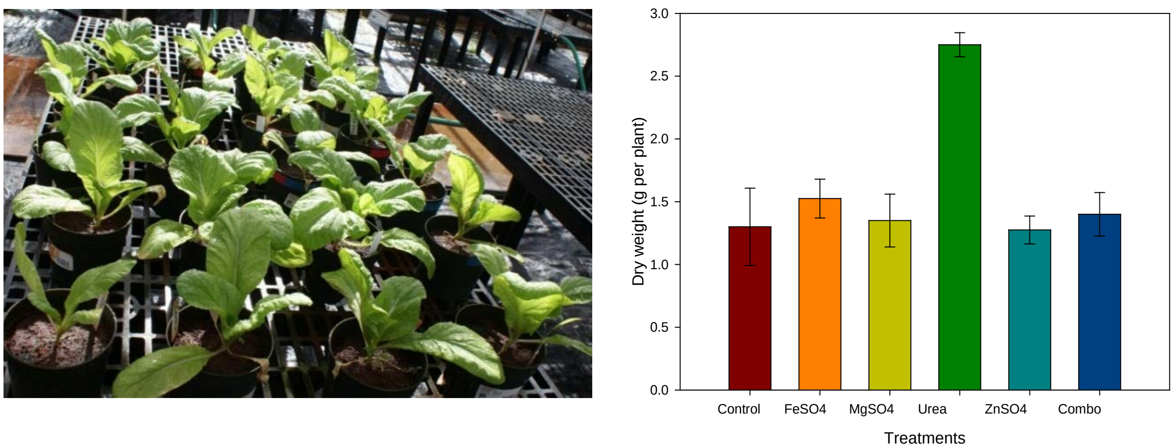


Figure 4. Chinese cabbage (Pak choi) and its dry weight as affected by the various soil treatments.

Table 1. Nutrient concentration in leaves of cabbage (Pak Choi) and chili pepper on a dry weight basis.

| | Nitrogen (%) | Carbon (%) | Protein (%) | Mg mg/kg | Mn mg/kg | Fe mg/kg | Zn mg/kg |
|---|---|---|---|---|---|---|---|
| **Pak choi** | | | | | | | |
| Control | 2.37 | 36.91 | 14.82 | 6097 | 304 | 281 | 174 |
| FeSO4 | 2.46 | 38.09 | 15.35 | 6105 | 387 | 416 | 179 |
| MgSO4 | 1.92 | 37.33 | 12.01 | 5411 | 233 | 227 | 141 |
| Urea | 3.13 | 36.89 | 19.58 | 8312 | 546 | 587 | 382 |
| ZnSO4 | 2.75 | 37.12 | 17.21 | 5234 | 302 | 221 | 234 |
| Combo | 1.97 | 37.57 | 12.29 | 6987 | 344 | 241 | 239 |
| **Chili pepper** | | | | | | | |
| Control | 1.62 | 40.01 | 10.15 | 11916 | 430 | 33 | 93 |
| FeSO4 | 1.83 | 39.87 | 11.43 | 13074 | 354 | 324 | 107 |
| MgSO4 | 2.46 | 40.96 | 15.37 | 13880 | 306 | 81 | 141 |
| Urea | 2.33 | 39.80 | 14.58 | 14758 | 529 | 533 | 101 |
| ZnSO4 | 1.90 | 39.91 | 11.91 | 14254 | 428 | 344 | 75 |
| Combo | 1.82 | 40.00 | 11.39 | 14706 | 415 | 326 | 103 |

**Chili pepper.** Average dry weights of chili pepper plants after 6 weeks ranged from 12 - 31 grams (fresh) and 0.3 - 0.73 grams (dry) per plant. The plants treated with urea had the highest plant fresh and dry weights (Figure 5). Tissue N and protein contents were the highest in urea treated plants (along with the $MgSO_4$ treatment) (Table 1), however, it appears that these levels of N applications were less than adequate for the chili pepper as suggested by the very low level of tissue N content across all treatments: The adequate level of N in chili pepper tissue before flowering stage is ≥ 4% (Maynard & Hochmuth, 2007).Very low nitrate ($NO_3$) levels (below 20 mg/kg) in the soil after harvest (Table 2) also suggests the possibility of N deficiency.

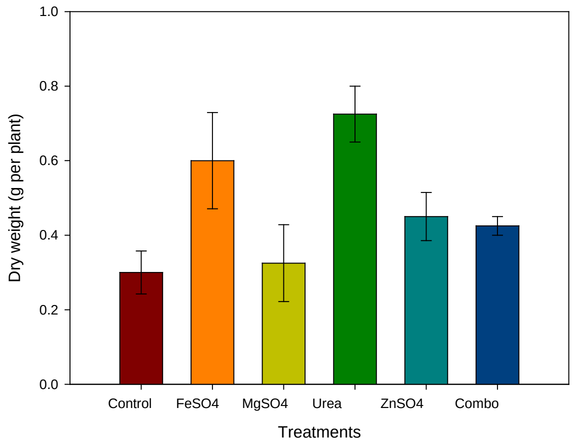


Figure 5. Chili pepper and its dry weight as affected by the various soil treatments.

Table 2. Nutrient content in soil after harvest. (soil pH was measured in water (20 g soil/20 mL water); $NO_3$ was extracted with 1 m*M* $CaCl_2$; other nutrients were extracted with the Mehlich-3 solution).

| Treatments | pH (1:1) | NO3-N (mg/kg) | Mg (mg/kg) | Mn (mg/kg) | Fe (mg/kg) | Zn (mg/kg) |
|---|---|---|---|---|---|---|
| **Pak choi** | | | | | | |
| Control | 6.99 | 5.4 | 240.44 | 599.88 | 22.18 | 16.09 |
| FeSO4 | 7.22 | 5.0 | 245.58 | 601.45 | 28.02 | 14.95 |
| MgSO4 | 7.11 | 4.6 | 263.46 | 591.87 | 21.43 | 14.43 |
| Urea | 5.76 | 5.4 | 181.76 | 553.04 | 27.53 | 13.29 |
| ZnSO4 | 7.06 | 5.4 | 217.29 | 567.03 | 21.28 | 21.15 |
| Combo | 7.01 | 4.8 | 273.51 | 577.64 | 23.33 | 18.85 |
| **Chili pepper** | | | | | | |
| Control | 6.71 | 3.8 | 258.10 | 685.53 | 28.19 | 15.35 |
| FeSO4 | 6.92 | 4.4 | 253.52 | 698.78 | 38.93 | 14.17 |
| MgSO4 | 6.53 | 5.6 | 293.88 | 713.87 | 28.71 | 14.97 |
| Urea | 6.48 | 7.4 | 281.61 | 647.88 | 30.41 | 16.29 |
| ZnSO4 | 6.88 | 3.0 | 258.54 | 660.14 | 30.98 | 18.04 |
| Combo | 6.32 | 6.2 | 325.64 | 653.61 | 33.36 | 22.13 |

**Conclusions and recommendations**:

- Nitrogen was the probable cause of the “Yellowing Problem”. The N fertilizer rates of 5 – 25 lbs/acre of N were not adequate for optimum vegetable growth.
- The use of calcium nitrate [$Ca(NO_3)_2$] should be discouraged in this situation. That is because $NO_3^-$ is readily leached out of the root zone under neutral soil pH (soil carries negative surface charge, thus cannot retain the negatively charged nitrate ions) and when receiving more than adequate rainfall.
- Ammonium producing fertilizers (e.g., urea, liquid ammonia, or ammonium sulfate) or slow-released organic N sources (e.g., compost, animal manure, meat meal) should be encouraged to address the yellowing of vegetation and increase plant yields.

**References**

Hue, N. V., S. Vega, and J.A. Silva. 2001. Manganese toxicity in a Hawaiian Oxisol affected by soil pH and organic amendments. Soil Sci. Soc. Am. J. 65: 153-160.

Hue, N. V. and Y. Mai. 2002. Manganese toxicity in watermelon as affected by lime and compost amended to a Hawaiian soil. Hort Sci. 37:656-661.

Hue, N.V., G. Uehara, R.S. Yost, and M.E. Ortiz-Escobar. 2007. Distribution of Soil Orders in Hawaii. J. Hawaiian Pacific Agric. vol. 14: 17-28

Maynard, D. N. and Hochmuth, G. J., 2007. Knott’s Hand book of Vegetable Growers. Fifth Edition by John Wiley & Sons, Inc., New Jersey.

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