SOIL FERTILITY STATUS OF PHILRICE CES RICEFIELDS IN MALIGAYA, NUEVA ECIJA BY SOIL ANALYSIS & MINUS-ONE-ELEMENT TECHNIQUE (MOET)

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In 2001, soils of 118 blocks of the PhilRice Central Experiment Station (CES) ricefields in Maligaya, Science City of Muñoz, Nueva Ecija, were sampled and comparatively evaluated for fertility limitations through the minus-one element technique (MOET) and soil analysis. Soil samples assigned for MOET were kept moist while samples for laboratory analysis were air-dried and sieved. Each MOET set included 8 pots filled with 4 kg saturated soil each assigned to one of the eight MOET-based fertilizer formulas: control, minus N, minus P, minus K, minus Zn, minus S, minus Cu, and complete (with N, P, K, Zn, S, Cu). The fertilizers were incorporated into the soil before seeding and N was applied 14 days after seeding (DAS). Five pre-germinated seeds of rice cultivar IR64 were initially sown into each pot, then thinned to three seedlings/pot at 14 DAS. The soil in the pot was maintained submerged and water depth was increased to 3-5 cm as the seedling grew taller. Weekly observations were made starting 14 DAS for the occurrence of nutrient deficiency symptoms, and for the measurement of plant height and tiller count. At 60 DAS, plants were harvested from the base for the measurement of leaf area (LA), leaf dry weight (LDW), stem dry weight (STDW), total shoot dry weight (TSDW) and relative shoot dry weight (RSDW). If the RSDW obtained was less than 80% of that in the complete formula, the soil was considered deficient. Likewise, soil analysis was done to measure pH, %OM, %OC, total N, available P, K, Zn, S and Cu. Soils with 0.2% total N, 6 ppm Olsen P, 0.2 cmol/kg soil exchangeable K, 1 ppm available Zn, 6 ppm available S and 0.2 ppm available Cu were classified as deficient.

Lack of N in the soil is the only common factor in all soils as determined by both approaches to analysis for soil nutrient deficiency, suggesting that this is the single most limiting factor in the growth of the rice plant. However, the MOET results indicate that majority of the soils (72.5%) are multiple element-deficient, ranging from 2 to 6 nutrient elements, and these cannot simply be ignored. Further evaluation of the MOET compared with the traditional soil analysis is recommended. In addition, the MOET can be validated through on-farm observational studies and calibrations.

Keywords minus-one element test, soil analysis, soil fertility limitations

INTRODUCTION

One of the most critical aspects of soil use and management is the maintenance of soil productivity, which is affected by soil nutrient status or soil fertility. Indeed, the ease with which many nutritional problems can be corrected and the spectacular results that often follow, have made soil fertility one of the more readily accepted aspects of soil management. In spite of its widespread popularity, however, the fundamentals of fertility control are not well understood, a fact that has frequently led to the improper use of fertilizers.

The paddy soil-rice system has an efficient nutrient-replenishing mechanism. This is shown in the fact that in some Asian paddy fields, rice has been cultivated for hundreds of years
without receiving any fertilizer and yet yields of 1.6 to 2 t/ha have been sustained (Kyuma 1996).

Intensified cropping with increased yield does remove substantial amounts of nutrients from the soil that must be replaced to sustain soil productivity. This having been ignored, the stagnation of rice yields as recently observed in the lowlands of Asia has become a major agronomic concern. Specific reasons for this include decreasing nutrient productivity and an increasing imbalance of nutrient supply versus its removal from the soil (Mutert 1996). Long-term fertility experiments on NPK fertilization conducted by the International Rice Research Institute (IRRI) has shown that rice responds initially only to nitrogen, but after 8-10 consecutive croppings, responses to P and/or K are observed (De Datta 1988, Cassman et al 1995). As crop yield increases, soil nutrients other than N, P and K are mined at increased levels (Descalsota et al 2000). Once nutrient imbalance takes place, maximum responses to major fertilizer applications are no longer obtained.

Descalsota et al (2000) evaluated soil fertility status of 144 paddy fields in 19 provinces in the Philippines to identify areas of multiple nutrient limitations. Based on normally accepted critical levels of several essential soil nutrient elements examined, only two sites had sufficient nutrient supply. Eleven sites had single nutrient deficiency and the remaining were multiple nutrient-deficient ranging from two to five nutrient elements. The study showed a growing number of rice areas becoming multiple nutrient-deficient.

Soil fertility limitations can be evaluated by soil analysis, field experiments, plant tissue analysis, observations on the incidences of deficiency or toxicity symptoms, and biological test. Recently a biological method known as minus-one element technique (MOET) was developed by PhilRice (Descalsota et al 1999, 2000, 2001). MOET is based on the principle that plant growth responds to the most limiting nutrients. The response partly is manifested as reduced plant height and tiller counts, delayed maturity, smaller panicles and by the presence of distinct discoloration such as chlorosis, necrosis and/or streaks. Results of past studies (Descalsota et al 1999) showed that MOET was able to identify incipient deficiencies, which could not be checked by soil analysis.

The present locations of PhilRice experiment stations represent a diverse spectrum of landscape and agro-pedological, as well as climatic conditions. Moreover, the inter- and intra-spatial variations among sites or stations could be attributed to the interaction effects of physical/natural factors and anthropogenic interactions. These factors often cause unexplained anomalies affecting yield results of experiments within PhilRice stations. To update the information of their fertility status, and to compare the efficacy of soil analysis and MOET in the description of soil fertility, soils of PhilRice Central Experiment Station (CES) ricefields were evaluated through both soil analysis and MOET in 2001. In this report, soil fertility limitations of PhilRice CES ricefields are identified.

**METHODOLOGY**

For the MOET and soil analysis, the entire PhilRice CES ricefields were considered. As the ricefields were composed of blocks separated by dikes and/or irrigation canals, composite soil samples (up to 20 cm deep) were collected from 118 blocks. A portion of each sample was air-dried and pulverized for the soil analysis and the other portion kept moist for the MOET.

A net house was installed to contain the MOET set. Each included eight plastic pots (20 cm in diameter and 18 cm in height) filled with 4 kg wet soil, assigned for the following nutrient fertilizer formulas: complete, control, minus N, minus P, minus K, minus Zn, minus S and minus Cu (Descalsota et al 1999). The soil in the pots was kept submerged for two weeks prior to seeding. The appropriate nutrients, except N, were applied and mixed within 3-5 cm of the soil surface before seeding. Nitrogen was added 14
days after seeding (DAS). Initially 5 pre-germinated seeds of rice cultivar IR64 were sown into each pot, then thinned to three seedlings/pot 14 DAS. The soil was kept submerged and water depth was increased to 3-5 cm as the seedlings grew taller. Tiller count and plant height were measured weekly starting 14 DAS. Observations were also made on plant growth patterns and on the occurrence of deficiency symptoms. At 60 DAS, the rice plants were clipped from the base and growth factors such as leaf area (LA), oven-dried weight of leaf (LDW), stem (STDW), and total shoot (TSDW) and relative shoot dry weight (RSDW) were measured. Soils where RSDW (% to that obtained from respective soil fertilized with complete fertilizer formula) was less than 80% were classified as deficient for the corresponding nutrient element (Descalsota et al 2000).

Likewise, soil samples were analyzed for pH (1:1 soil: water), organic carbon (OC) and organic matter content (OM) (by Walkley-Black method), total N (Kjeldal method), available P (Olsen method), exchangeable K (ammonium acetate), available Zn (DTPA), S (turbidimetric method), and available Cu (DTPA). Following the values accepted as critically low levels of soil nutrient content in lowland rice ecosystems (Table 1), soils with equal to or less than 0.2% N, 6 ppm Olsen P, 0.2 cmol/kg soil exchangeable K, 1 ppm available Zn, 6 ppm available S and 0.1 ppm available Cu, were identified as deficient in those specific nutrients.

RESULTS

pH

The soil pH not only influences the occurrence of disease but also the availability of nutrients for plant growth. Based on soil analysis, soil pH averaged 5.73 with majority of the soils (77.5%) having pH equal to or less than 6.1 (Figure 1).

There can be severe Fe toxicity in an acid sulfate soil (Solivas & Ponnamparkeruma 1980). For acid or sulfate soils, there are at least three approaches. One is breeding and selection for tolerance to stress; two is soil amendment; and three is mixed cropping.

Torres et al (1988) found that upland rice was compatible with cowpeas in upland soils of pH 4.6-5.0.

Garrote et al (1986) found that in a highly acidic site (pH 4), application of N alone was detrimental to crop growth. This was a study to develop an appropriate fertility management strategy for upland rice on acid infertile soils.

Thanh-Tuyen & Dionzon (1991) reported on their study of generating variability in upland rice cultivars through somaclonal variation for developing stress-tolerant lines, specifically to acidic soils (pH 4.8-5.2) in Leyte.

Organic Matter

Organic matter (OM) content of majority of the soils (82.9%) was more than 2%; the overall average was 2.46% (Figure 2), which can be considered a moderate level of OM.

Mandac & Herdt (1978) reported that the more technically efficient farmers in the Philippines were located in ‘the better-endowed environments or in soils with more organic matter.’

Even so, the soil pH and organic matter content of the soil could be high but available Zn could be low (Abilay Jr & De Datta 1978).

A study by Quidez (1978) showed that soils high in organic matter but were poorly drained could be deficient in available P, exchangeable K, and available Zn.

Interestingly, Lantin et al (1990) reported that in the Philippines, rice production is limited by problems such as acid sulfate soils and soils with excess organic matter.

The MOET

The soils in the MOET setup were evaluated through RSDW. RSDW in minus N averaged 21.5% and was almost similar to that of control (21.4%); that of minus P was 78.2%; that of minus K was 92.58; that of minus Zn was 95.4%; that of minus S was 71.92%; and that of minus Cu was 98.94% (Table 2).
Nitrogen

Figure 3A graphs the data on total N (%) as determined by soil analysis and Figure 3B as determined by MOET. The differences in the respective data are due to the nature of the respective analysis. This is in view of the fact that soil analysis measures what is in the soil while the MOET measures indirectly the amount of nutrient that was (or was not) taken by the plant from the soil. Interestingly, Figure 3A shows that 26.5% of the soils had total N equal to or less than 0.1%, and the N content of the rest of the soils ranged from 0.1% to 0.19%.

Figure 3B shows that the RSDW equal to or less than 80% for minus N averaged 21.5% and was almost equal to that of the control (21.4%).

Available P

The data by soil analysis shows that available P ranged from 5.2 to 51 ppm, with an average of 13.7 ppm (Figure 4A).

The data by MOET shows that the RSDW equal

Table 1. Accepted values of critically low levels of soil pH and nutrient elements in a lowland rice ecosystem

<table>
<thead>
<tr>
<th>Description</th>
<th>Accepted values of critically low level</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>3-4 extremely acid</td>
<td>BSWM, personal communication</td>
</tr>
<tr>
<td></td>
<td>4-5 acidic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5-6 Slightly acidic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6-7 slightly neutral</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 7 alkaline</td>
<td></td>
</tr>
<tr>
<td>Organic matter content (%)</td>
<td>Less than 1%</td>
<td>BSWM, personal communication</td>
</tr>
<tr>
<td>C : N ratio</td>
<td>&gt;50 presence of high amounts of biomass</td>
<td>BSWM, personal communication</td>
</tr>
<tr>
<td></td>
<td>15-30 well humified</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 optimum</td>
<td></td>
</tr>
<tr>
<td>Total N (%)</td>
<td>&lt; 0.2% low</td>
<td>Descalsota et al (1999)</td>
</tr>
<tr>
<td></td>
<td>5-10 ppm medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 10 ppm high</td>
<td></td>
</tr>
<tr>
<td>Exchangeable K (cmol/kg soil)</td>
<td>&lt; 0.2 cmol/kg soil low</td>
<td>Doberman and fairhurst (2000)</td>
</tr>
<tr>
<td>Available Zn (ppm)</td>
<td>≤ 1 ppm low</td>
<td>Doberman and fairhurst (2000)</td>
</tr>
<tr>
<td>Available S</td>
<td>≤ 6 ppm low</td>
<td>Doberman and fairhurst (2000)</td>
</tr>
<tr>
<td>Available Cu (ppm)</td>
<td>≤ 0.1 ppm low</td>
<td>Doberman and fairhurst (2000)</td>
</tr>
</tbody>
</table>
to or less than 80% for minus P was 78.2%, indicating that many of the soils are deficient in phosphorus.

**Exchangeable K**
As determined by soil analysis, with an average of 0.23 cmol/kg soil, exchangeable K ranged within 0.1 to 0.6 cmol/kg soil, with majority (75.2%) having exchangeable K equal to or less than 0.2 cmol/kg soil (Figure 5A).

By the MOET, the RSDW equal to or less than 80% for minus K was 92.58% (Figure 5B). This indicates that most of the soils are deficient in the nutrient K.

**Available Zn**
By soil analysis, most of the soils (85.6%) were identified with available Zn of more than 1 ppm, with a small percentage (4.25%) having available Zn more than 5 ppm (Figure 6A). Soil available Zn averaged 2.68 ppm and ranged from 0.49 ppm to 8.3 ppm.

Measured by the MOET, the RSDW equal to or less than 80% for minus Zn was 92.5% (Figure 6B). This indicates that most of the soils are deficient in Zn.

**Available S**
By soil analysis, available S averaged 13 ppm with 61.5% of the soils having available S more than 10 ppm (Figure 7A).

By the MOET, the RSDW equal to or less than 80% for minus S was 69.2%, indicating S deficiency in majority of the soils (Figure 7B).

**Available Cu**
By soil analysis, all the soils were identified with high amounts of available Cu, with an average of 12.40 ppm within the range of 1.4 to 22.4 ppm (Figure 8A).

By the MOET, the RSDW equal to or less than 80% for minus Cu was 32.4%, which indicates that about one third of these soils are deficient in this soil nutrient.

**Relative Yield Of Control**
Similar to minus N, the RSDW of the control was much lower than 80% (Figure 9). This means that the control lacks N.

### Table 2. Relative yield of rice cultivar IR64 obtained by the minus-one-element technique (MOET)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average Relative Yield (g.g⁻¹.10²)</th>
<th>Range (g.g⁻¹.10²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>21.4</td>
<td>9-44</td>
</tr>
<tr>
<td>-N</td>
<td>21.5</td>
<td>9-45</td>
</tr>
<tr>
<td>-P</td>
<td>78.2</td>
<td>17.2-163</td>
</tr>
<tr>
<td>-K</td>
<td>92.5</td>
<td>20-160</td>
</tr>
<tr>
<td>-Zn</td>
<td>95.4</td>
<td>61-187</td>
</tr>
<tr>
<td>-S</td>
<td>71.9</td>
<td>15-157</td>
</tr>
<tr>
<td>-Cu</td>
<td>98.9</td>
<td>44-156</td>
</tr>
</tbody>
</table>

80% for minus K was 92.58% (Figure 5B). This indicates that most of the soils are deficient in the nutrient K.

**DISCUSSION**

Presenting the results of the two approaches to the determination of soil nutrient deficiency,
Figure 10 shows the comparative extent of deficient soils in particular nutrient element(s) based on soil analysis and the MOET. Overall, the data shows that the findings of these two different approaches are strikingly very different, except for N, where 100% of the soils were identified deficient by both evaluation tests. This suggests that N is the most deficient of all the nutrients.

With the rest of the individual nutrients, the data indicates the great differences in the deficiency values between those determined through soil analysis and through the MOET. On one hand, the MOET finds deficiencies in five nutrients other than N – P, K, Zn, S, and Cu – ranging from 20% of the soils to 45%. On the other hand, the soil analysis finds no soils with deficiency in Cu, and only a few soils with deficiency in P; it finds a little more of the rest of the soils deficient in Zn (10%) and in S (5%).

Reyes et al (1985) found that 65% of the soils they studied were N deficient and over 57% were Zn deficient, less than 25% deficient in P or K. Descalsota et al (2003) studied the fertility status of 144 sites in the Philippines through soil analysis and found that 90% of the sites were deficient in 2 or more nutrients. The group of Descalsota is the one who developed the MOET; one of their recommendations in the paper cited above was to use ‘proven technical procedures in assessing or characterizing’ farms, and/or the ‘development of simplified techniques in nutrient assessment,’ implying the MOET.

In the current study, by the MOET majority of the soils (72.5%) were found to be multiple element-deficient, ranging from 2 to 6 nutrient elements (Figure 11). In 1990, Lantin et al reported that cultivated rice suffered from multi-deficiencies: N, P, Zn, S, and Fe. In the Descalsota et al paper cited above (2003), 42% of the sites studied were found multiple-deficient in nutrients.

Nitrogen deficiency appears to be the one and only common factor in all soils as determined by both approaches to analysis for soil nutrient deficiency. There are two ways to look at this finding, and these are:

One view is to propose that N is the most important factor enhancing vegetative growth of the rice plant. According to Brady (1984), nitrogen is a regulator that governs to a considerable degree the utilization of K, P and other nutrient constituents with all plants. The amount of N in available form is small, while the quantity withdrawn annually by crop is comparatively large (Brady 1984). According to De Datta (1981), a rice crop yielding 7.9t/ha rough rice and 7t/ha straw removes a total of 123 kg nitrogen from the soil. Much of the nitrogen in the soil is actively lost from the plant soil system by plant uptake and removal, leaching, erosion, and emission of gaseous compounds. In this study, as the RSDW values of minus N and the control are compared, the collective impact of other nutrient elements seems negligible.

Another view is to propose that it is no longer valid to assert that N is the most limiting nutrient in lowland rice soils (Descalsota et al 2003). In the current study, the soils were found to have deficiencies not only in N but also in P, K, Zn, S, and Cu, ranging from 20% to 45% of the soils analyzed.

While exchangeable K of 75% of the soils was around the critical level of 0.2 cmol/kg soil the frequency of soils identified as K-deficient was much lower in MOET. According to Tandon & Sekhon (1988), the non-exchangeable fraction of K also makes a major contribution of the K absorbed by crops, thus measurement of available K can also take this fraction into account. The non-exchangeable form of K is in dynamic equilibrium with the available forms and, therefore, acts as an important reserve of slowly available K.

Interactive effect of nutrients may either enhance or depress availability and or uptake of a particular nutrient element. Luxurious growth of plants may also accelerate depletion of nutrient elements especially micronutrients which otherwise can be in enough amounts to meet normal growth of plant. Davide (1960) concluded that the beneficial effect of flooding on
P depends on the intensity of redox condition of submerged soil and Fe content. Studies at IRRI indicate that P fixation in flooded rice is rapid in acid and neutral soils (De Datta 1981). The fixation of P is considerably slower in slightly alkaline soils. Soils containing hydrated Fe and Al oxides, hollysites, and allophanes fix P in both upland and lowland soils (De Datta 1981). Zn uptake is depressed because of an increase in Fe, Ca, Mn, Cu, and P after flooding. In flooded soils, formation of Zn-phosphate or ZnS reduces soil available Zn to the plants. The mobility of Zn is affected by pH, percentage of clay, organic matter, Ca and P status. Giordano et al (1974) showed that Fe and Cu strongly depress both Zn uptake and translocation. Heavy NPK or nitrogen fertilizer application intensifies Cu and Zn deficiencies.

**RECOMMENDATIONS**

Inasmuch as results of the MOET differ much from the results of the soil analysis, it is recommended that further comparative evaluation of the MOET compared with the traditional soil analysis be need. The MOET can be validated through on-farm observational studies and calibrations.

**Acknowledgement**

The efforts of M Constancia from BSWM, Mr Richard V Carnage and Mr Numeriano J Corpuz from PhilRice CES are hereby acknowledged.

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Fig 1. Frequency distribution of PhilRice CES crop field soils for pH

Fig 2. Frequency distribution of PhilRice CES crop field soils for organic matter content (%)
**Fertility Status Of PhilRice CES Soils**

**Fig 3. A Frequency distribution of PhilRice CES crop field soils for Total N (%)**

**Fig 3. B Frequency distribution of PhilRice CES crop field soils for RSDW in minus N element test**
Fig 4. A Frequency distribution of PhilRice CES crop field soils for available P (ppm)

Fig 4. B Frequency distribution of PhilRice CES crop field soils for RSDW in minus P element test
Fig 5.A Frequency distribution of PhilRice CES crop field soils for exchangeable K

Fig 5.B Frequency distribution of PhilRice CES crop field soil for RSDW in minus K element test
Fig 6. A Frequency distribution of CES crop field soils for available Zn

Fig 6. B Frequency distribution of PhilRice CES crop field soils for RSDW in minus Zn element test
Fig 7.A Frequency distribution of PhilRice CES crop field soils for available sulfur

Fig 7.B Frequency distribution of PhilRice CES crop field soils for RSDW in minus S element test
Figure 8A: Frequency distribution of PhilRice CES crop field soils for available Cu

Available Cu (ppm)

Fig 8A Frequency distribution of PhilRice CES crop field soils for available Cu
Fig 9. Frequency distribution of PhilRice CES crop field soil for relative yield in control

Fig 10. Frequency of soils identified deficient thru minus-one element test and soil analysis
Fig 11. Frequency of soils identified in one or more elements through MOET