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# Site Specific Fertilizer Recommendations for Maize (*Zea mays* L.) Grown in Reddish Brown Earth and Reddish Brown Latasolic Soils

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***ABSTRACT:*** *Site specific fertilizer recommendations optimize crop production while minimizing nutrient losses. This study was conducted to identify soil fertility constraints of Reddish Brown Earth (RBE) in $DL_{1b}$ and Reddish Brown Latosolic (RBL) soil in $IM_{3c}$ and to formulate site specific fertilizer recommendations for Maize (Zea mays L.). Low productive fields from Mahailluppallama (MI) and Dodangolla (KS) in Sri Lanka were selected based on available farm records and soil fertility survey. Soil samples were analyzed for basic soil properties using standard methods and available nutrients ($NH_4^+$-N, P, K, Ca, Mg, S, Fe, Mn and Zn) were determined using multi-element extractions. The nutrient concentrations for optimum treatments were formulated based on available nutrients and fixation capacity of nutrients. The formulated nutrient requirements were tested in a greenhouse experiment using missing element technique. Soil nutrient analysis indicated the deficient levels of N, P, S, Ca, Zn and Cu for RBE soils and N, P, K, S, Ca, Zn, Cu and Mn for RBL soil. Lower fixation capacity of P and higher fixation capacity of S were observed in RBL, than that of RBE. In the greenhouse experiment, both soils showed the highest dry matter yield in the optimum nutrient treatment and significant differences were observed in minus treatments of Ca, S and Zn for RBE and P, Ca, S and $CaCO_3$ for RBL soil. Site specific fertilizer requirements for maize were identified for the two tested soils, which could be utilized for achieving potential yield.*

**Keywords:** *Available nutrients, greenhouse experiment, nutrient fixation capacity, site specific fertilizer recommendation*

## INTRODUCTION

Soil fertility determines the capacity of a particular soil to provide essential plant nutrients. A fertile soil's physical and biological properties facilitate healthy root growth and ensure retention of nutrients over a long period of time. According to Hornic & Pair (1987) infertile soils exist all-around the world. Kumaragamage & Indraratne (2011) reported most of the Sri Lankan soils are deficient in N, P, K, B and S and some soils are deficient in Ca, Mg and some micronutrients. Supply of required quantities of plant nutrients according to the demand of the plant in balanced quantities is not commonly practiced and it could be the main soil fertility constraint restricting crop growth in Sri Lanka. Conversion of infertile soils in to productive soils could be achieved by addressing soil fertility issues. Site specific

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nutrient management is one of the important tools to address low productivity in agricultural soils.

For certain crops, farmers in Sri Lanka apply inadequate quantities of plant nutrients while more than the required quantities of plant nutrients and organic manure are applied for some other crops (Wijewardana & Amarasiri, 1990) resulting many environmental problems (Pitumpe Arachchige & Indraratne, 2011). Site specific nutrient management approaches correct nutrient deficiencies and avoid excess application, which could lead to minimize environmental pollution. Hence, site specific fertilizer application is favorable for environmental protection and farmer's economy. Practice of site specific fertilizer recommendation optimizes the crop production and minimizes the nutrient losses from soil (Ferguson *et al.,* 2002). Due to insufficient supply of plant nutrients, yields of the annual crops in Sri Lanka are much less than the world average (Wijewardana, 1994; Bandara *et al.,* 2006).

A Systematic approach proposed by Portch & Hunter (2002) is used to formulate site specific fertilizer recommendation. This approach was validated for soils of Sri Lanka by Kumaragamage & Indraratne, (2011) using soils from 32 different locations in Sri Lanka. Further this approach has been tested for many annual crops in different parts of the world (John *et al.,* 2007; Pasuquin *et al.,* 2010; Paramasivan *et al.*, 2011) and Sri Lanka particularly for rice (Bandara *et al.,* 2005; Bandara *et al.,* 2006) and for some vegetables (Amarasekara *et al.,* 2007; Keerthisinghe *et al.,* 2008; Herath *et al.,* 2013) resulting larger yield and economic benefits. Maize is grown in many parts of the country with blanket application of only N, P and K fertilizers. This may be one of the reasons for low yields obtain by the farmers and hence, it is important to test whether a site specific fertilizer recommendation could be used to overcome this yield ceiling. This study was therefore conducted to identify soil fertility constraints and to formulate a site specific fertilizer recommendation for Maize grown in the low productive lands located at two agro-ecological zones of Sri Lanka.

## MATERIALS AND METHODS

Experiments were conducted at Field Crop Research and Development Institute *Mahailluppallama*, at low country dry zone (DL1b) where soil is Reddish Brown Earth (RBE: Typic Rhodustalfs) (De Silva & Dassanayake, 2010) and field at the University Experimental Station, *Dodangolla*, *Kundasale* at intermediate zone mid country (IM3c) where soil belongs to Reddish Brown Latosolic soils (RBL; Rhodudalfs) (De Silva *et al.,* 2005). Low productive fields were selected by the available farm records from both locations. Sixteen soil samples were collected at a depth of 0-20 cm using grid method and a representative composite soil sample was prepared for each field. Six replicates of the composite soil samples were analyzed for selected physical and chemical characteristics.

### Soil analysis

Soil pH was determined in a 1:2.5 soil: distilled water suspension. Soil EC was determined in soil suspension prepared by 10 g soil with 50 ml distilled water (1:5 soil: water) and measured by digital Electrical Conductivity meter. Organic matter content was determined by digestion with an acid dichromate solution and titrating with ferrous ammonium sulphate according to modified Walkley and Black method (Nelson & Sommer, 1996). Cation Exchange Capacity was determined using $NH_4OAC$ buffer solution at pH 7 (Summer &

Miller, 1996). Soil texture was determined by pipette method (Gee & Dani, 2000). Available nutrients were extracted by three step extraction procedure described by Portch & Hunter (2002). Available P, K, Cu, Fe, Mn and Zn were determine by shaking 2.5 g of soil with 25 ml of extraction solution which contains 0.25 *M* $NaHCO_3$ + 0.01 *M* EDTA + 0.01 *M* $NH_4F$. Active acidity, $NH_4^+$ - N, exchangeable Ca and Mg were determined by shaking 2.5 g of soil with 25 ml of 0.1 *M* KCl solution, while available S was extracted by 5 g of soil with 25 ml of 0.08 *M* calcium phosphate solution. For all the analysis shaking time was 10 min. Extracted K, Cu, Fe, Mn, Zn, Ca and Mg were determined by Atomic Absorption Spectrophotometer. The extracted P was determined by the molybdenum blue method (Murphy & Riley, 1962) and $NH_4^+$–N was determined using indophenols blue colorimetric method and measuring absorbance at 630 nm. Concentrations of Sulfate ($SO_4^{2-}$) S were determined by turbidimetric procedure (Portch & Hunter, 2002).

## Nutrient Fixation study

A fixation experiment was conducted for P, S and K to determine their requirements for soil. Five concentration levels with two replicates were used for each testing nutrient. The nutrient concentrations used for nutrients were 20, 40, 80,160 and 320 mg $kg^{-1}$ for P; 10, 20, 40, 80 and 160 mg $kg^{-1}$ for S; and 25, 51, 102, 203 and 407 mg $kg^{-1}$ for K. For P and K fixation treatments 2.5 ml of solution containing required concentration were added to 2.5 g of soil while 5 ml of solution containing S were added to 5 g of soil. P, K and S treated soils allowed to dry for 5 days and elements were extracted using the same procedure described above. The amount of each nutrient to be added was determined using the graph plotted between the quantities of nutrient extracted against the quantities of nutrient added to the soil.

Nutrient requirements for deficient nutrients were calculated based on critical limits (Table 3) proposed by Portch & Hunter (2002). Molybdenum was added to the soil at a rate of 1 mg $kg^{-1}$ only if the pH was less than 6.5. Amount of $CaCO_3$ to be applied was calculated using following formula (Portch & Hunter, 2002).

$$CaCO_3 \text{ to be applied (g100 g}^{-1}\text{ soil)} = \text{Active acidity (cmol kg}^{-1}\text{) x 0.10}$$

## Greenhouse experiment

Modified missing element technique (Portch & Hunter, 2002) was used to evaluate the status of the individual nutrient. Nine treatments for RBL and six treatments for RBE soils were used including Optimum (OPT) treatment (Table 1) based on the nutrient status of the soil. Optimum treatment was supplied with nutrients which were calculated using expected sufficient level in soil (Table 3) and initial nutrient status. Individual nutrient statuses were equal to that of the OPT in all other treatments but different with respect to the testing element or $CaCO_3$. When the nutrient was present at sufficient concentration, it was not supplied. When nutrient was deficient in the soil, it was supplied. Experiment was conducted as complete randomized block design with four replicates. Maize (variety-*Sampath*) was grown as the test crop. Pots were kept in greenhouse for one month. Capillary irrigation system was used to maintain the moisture level. Plants were harvested after one month and dry weight of shoots were obtain by oven drying at 60 $^0$C. Relative dry matter yields were calculated using the formula given below.

$$\text{Relative yield} = \frac{\text{Dry mattrer yield of the treatment}}{\text{Dry matter yield of the optimum treatment}} \times 100$$

Data were analyzed using MIXED procedure in SAS statistical software (SAS Institute, Inc 2005). Significant levels are considered as $P< 0.05$ for all analysis**.**

**Table 1. Treatments of the greenhouse study with missing element technique for *RBE* and *RBL* soils**

| Treatments | | Status of the treatment** |
|---|---|---|
| RBE | RBL | |
| Opt | Opt | All nutrients at sufficient level# |
| N | N | Minus N |
| P | P | Minus P |
| Ca | Ca | Minus Ca |
| S | S | Minus S |
| Zn | Zn | Minus Zn |
| NA* | K | Minus K |
| NA | Mo | Minus Mo |
| NA | $CaCO_3$ | Minus $CaCO_3$ |

*. not applicable
** all nutrients maintained at sufficient level except for the nutrient indicated as minus
# amounts indicated in the Table 3

## RESULTS AND DISCUSSION

Initial soil characteristics measured for RBE and RBL are shown in Table 2. CEC is moderate and OM contents are comparable in both soils and soil reaction is acidic only in RBL. Texture of the RBL soil was sandy loam and RBE soil belongs to the sandy clay loam. The EC in RBE soil was 0.12 dS $m^{-1}$ while that of RBL soil was 0.10 dS $m^{-1}$.

**Table 2. Initial soil properties of RBE at *Mahailluppallama* and RBL at *Kundasale*. V alues in parentheses are the standard deviation (n=6) of these estimates**

| Parameter | RBE | RBL |
|---|---|---|
| pH (1:2.5, soil:$H_2O$) | 7.1(±0.42) | 5.6(±0.21) |
| CEC ($cmol_+ kg^{-1}$) | 16.0(±1.40) | 13.5(±1.20) |
| Clay (%) | 27(±0.81) | 19(±0.74) |
| Silt (%) | 12(±0.67) | 15(±0.73) |
| Sand (%) | 61(±0.85) | 66(±0.71) |
| OM (%) | 1.5(±0.07) | 1.3(±0.04) |
| EC (dS $m^{-1}$) | 0.12(±0.03) | 0.10(±0.02) |
| Active acidity (cmol $kg^{-1}$) | ND* | 0.3(±0.01) |

*Not detectable

Both RBE and RBL soils were deficient with N, P, S, Ca, Zn and Cu when compared to the optimum concentrations (Table 3) described by Portch & Hunter (2002). Deficient levels of N, P, K and S in Sri Lankan soils were reported previously (Amarasinghe & Premadasa, 1982; Madurapperuma & Kumaragamage, 2007). In RBL soil, K and Mn were below the optimum level but not in RBE. Kumaragamage & Indrartne (2011) reported 31 soils had K concentration below the optimum concentration out of 32 soil samples collected from different locations in Sri Lanka.

Available phosphorus concentrations were low in both RBE and RBL soils (Table 3). Concentration of available P of less than 15 mg $kg^{-1}$ was observed for 78% soils among selected soils from 32 locations in Sri Lanka (Kumaragamage & Indrarathne, 2011). Portch & Hunter (2002) reported that range of Ca/Mg ratio should be 4.0 to 11.6 and for Mg/K ratio 1.6 to 4.7 for favorable crop production. Ratio of Ca/Mg which is not balanced in RBE soil had to be adjusted according to the range described by Portch & Hunter (2002). Deficiency of Ca and Mg has been found in few locations in Sri Lanka (Wijebandara & Ranasinghe, 2004; Kumaragamage & Indraratne, 2011). Advantages of added N, P and K could be fully realized only if secondary and micronutrient deficiencies are corrected (Amarasekara *et al.,* 2007). In Sri Lanka, Zn deficiencies have been reported in many agricultural soils (Nagarajah *et al.*, 1983). Zinc and Cu deficiencies were observed in both fields, but Fe concentration was at sufficient level (Table 3).

**Table 3. Optimum nutrient concentration (mg $kg^{-1}$) proposed by Portch and Hunter (2002) and available nutrient concentrations (mg $kg^{-1}$) in RBE at *Mahailluppallama* and RBL at *Kundasale*. Values in parentheses are the standard deviation (n=6) of these estimates**

| Parameter | Optimum | RBE | RBL |
|---|---|---|---|
| NH4-N | 100 | 2 (±0.57)D# | 5 (±1.17)D |
| P | 48 | 19 (±3.81)D | 22 (±0.13)D |
| K | 196 | 230 (±1.29) | 88 (±2.57)D |
| Ca | 1202 | 1048 (±3.70)D | 1124 (±53.9)D |
| Mg | 304 | 738 (±18.20) | 371(±11.52) |
| $SO_4^{2-}$-S | 40 | 22 (±1.31)D | 16 (±1.31)D |
| Zn | 6 | 1.3 (±0.21)D | 0.77 (±0.14)D |
| Fe | 30 | 35 (±3.42) | 33 (±4.10) |
| Mn | 15 | 31 (±2.89) | 12(±2.48)D |
| Cu | 4 | 2.9(±0.84)D | 2.23(±0.91)D |

#Deficient

Fixation capacities were different between two soils for different nutrients. Fixation of P in the RBL soil was lower than that of the RBE soil. To obtain optimum level of P, soils should be amended with 70 mg P $kg^{-1}$ for RBE and 50 mg P $kg^{-1}$ for RBL soils (Figure1a). The P fixation capacity of soils depends on OM%, CEC, pH and soil texture. A study conducted using soils from 52 locations in Sri Lanka found that P fixation showed significant relationship with OM% and available Fe concentration (Indraratnne & Thilakarathne, 2009). At higher levels, addition of S in RBE fixes more S than in RBL (Figure 1b). As S is highly mobile nutrient, high rainfall and intensive irrigation remove S from the effective root zone (Brady and Weil 1998). Fixation of S in both fields was moderate according to this study (Figure 1b). According to the S fixation 28 mg $kg^{-1}$ and 40 mg $kg^{-1}$ S should be added for RBE and RBL soil respectively to achieve sufficient level of S. Fixation of S in the soil depends on nature and extent of the active oxide surface, clay content, pH and amount of phosphate present in soil (Indraratne & Thilakarathne, 2009).

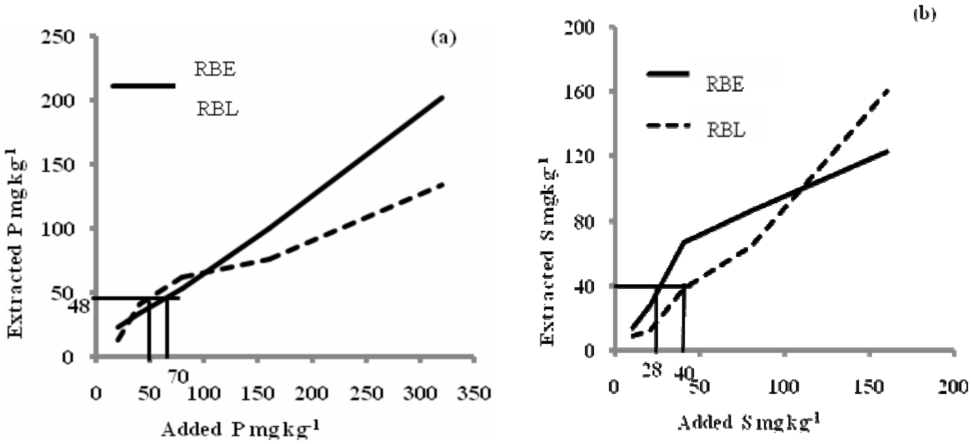


**Fig. 1. Fixation curve for Phosphorous (a) and Sulphur (b) indicating amount of nutrient extracted as nutrient added for RBE at *Mahailluppallama* and RBL at *Kundasale* soils**

The nutrient fixation study revealed that RBL soil fix K thus, accordingly 260 mg $kg^{-1}$ K should be added to the RBL soil to extract the optimum level of K (196 mg $kg^{-1}$) (Figure 2). Vermiculite and kaolinite are the major clay minerals found in the RBL at *Kundasale* (Indraratne, 2010) and therefore high K fixation may be linked with the presence of vermiculite clay in the RBL soil. Herath *et al.* (2013) observed high fixation capacity for K in RBL at *Kundasale* and high capacities of nutrient fixing had been previously reported using many soils with varying properties in Sri Lanka for P, K and S (Kumaragamage & Indraratne, 2011).

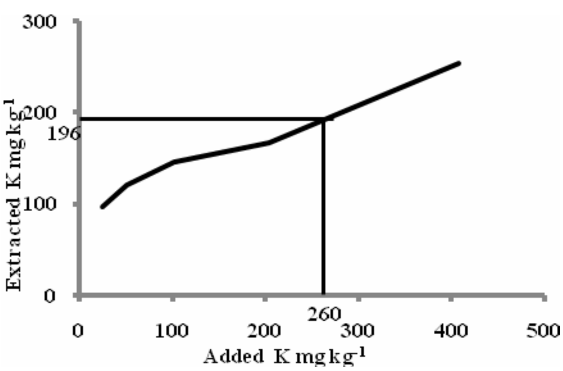


**Fig. 2. Fixation curve for K indicating amount of K extracted as nutrient added for the RBL at *Kundasale***

Mean dry matter yields and the relative yields are shown in the Table 4. Mean dry matter yield ranged from 1.57 g – 1.36 g in RBE and 1.29 g – 0.49 g in RBL. When compared the treatments of RBE, highest dry matter yields were observed in the OPT and minus N treatments, while lowest was recorded in the minus Ca treatment. Yield differences were not statistically significant for minus N and minus P in comparison with OPT for RBE. Minus treatments of Ca, S and Zn were significantly lower than the OPT treatment in RBE. In the RBL highest dry matter yield was observed in the OPT treatment and the lowest was observed in the minus Ca treatment. The mean dry matter yield of the minus treatments of P, S, Ca and $CaCO_3$ treatments were significantly lower in the RBL in comparison to the OPT treatment. Even though Zn and K were deficient in RBL soil according to the soil analytical results, it was not reflected from the results of the greenhouse study. Similar results were observed by Kumaragamage & Indraratne (2011) where no response was recorded for some K deficient soils added with K.

**Table 4. Mean dry matter yield and relative yield of the tested treatments in the greenhouse study for RBE at *Mahailluppallama* and RBL at *Kundasale***

| | RBE | | RBL | |
|---|---|---|---|---|
| | **Mean Dry matter yield (g)** | **Relative yield (%)** | **Mean Dry matter yield (g)** | **Relative yield (%)** |
| Optimum | 1.57[a*] | 100 | 1.29[a] | 100 |
| minus N | 1.53[a] | 97 | 0.94[a] | 72 |
| minus P | 1.47[a] | 93 | 0.58[b] | 45 |
| minus Ca | 1.36[b] | 86 | 0.49[b] | 38 |
| minus S | 1.42[b] | 90 | 0.90[b] | 70 |
| minus Zn | 1.46[b] | 92 | 1.04[a] | 81 |
| minus K | NA[#] | NA | 1.05[a] | 81 |
| minus Mo | NA | NA | 1.02[a] | 79 |
| minusCaCO3 | NA | NA | 0.84[b] | 65 |

*means followed by the same letter in a given column are not significantly different ($p<0.05$); [#]not applicable

Kumaragamage & Indraratne, (2011) reported OPT concentrations of some nutrients need to be adjusted before using them in a fertilizer recommendation. Further this approach uses to identify nutrient requirement based on soil but not on crop requirement. Therefore, fertilizer recommendations were formulated by considering the greenhouse data, initial nutrient concentrations and also present recommendation for maize given by the Department of Agriculture (DOA, 2013) (Table 5). Minus treatments of N and P did not show yield difference with OPT treatment for RBE soil and even K was not deficient for RBE soil. Hence DOA recommendation was considered for N, P and K for RBE soil, as crop specific requirements were not tested in this experiment. Similarly, RBL did not show yield difference with OPT for minus treatments of N and K but significant yield increment observed with added P. Therefore, DOA recommendation considered for N and K while P recommendation modified according to the results of the greenhouse study (Table 5).

**Table 5. Formulated site specific fertilizer recommendations for RBE at *Mahailluppallama* and RBL at *Kundasale***

| Nutrient | Department of Agriculture recommendation# | Site Specific Recommendation for RBE | Site Specific Recommendation for RBL |
|---|---|---|---|
| | -------------------------------- | kg $ha^{-1}$ | -------------------------------- |
| Urea | 325 | 325 | 325 |
| TSP | 100 | 100 | 200 |
| MOP | 50 | 50 | 50 |
| Ca | NA* | 300 | 160 |
| S | NA | 5 | 5 |
| Zn | NA | 2 | NA |
| $CaCO^3$ | NA | NA | 600 |

* not applicable
\# DOA (2013)

As minus Ca showed significant yield reduction for both RBE and RBL, recommendation for Ca is considered as same amount which was added to the greenhouse experiment (Table 5). Adding of Ca to these soils should be very critical and have to consider the soil pH and source of the Ca when apply Ca to the soil. Though S was deficient in both soils, minus S treatment did not show any significant yield reduction at the greenhouse level. Hence only 5 kg/ha of S recommended for the field experiment based on the previous personnel experience with RBL at *Kundasale* (Indraratne, personnel communication). The yield reduction for Zn was not significant compared with the OPT treatment for RBL while RBE giving significant yield reduction in minus Zn. Accordingly, site specific fertilizer recommendations formulated for RBE and RBL based on soil analysis, fixation study and greenhouse experiment are shown in Table 5. Further refinement is necessary to evaluate crop specific requirements of nutrients.

## CONCLUSIONS

Initial soil analysis of the low productive lands indicate the deficient levels of N, P, S, K, Ca, Mn, Cu and Zn. Both RBE and RBL soils had low fixation capacity for P and S but high K fixation was observed for RBL. Nutrient availability for cultivation of maize for RBE at *Mahailluppallama* was different from that of RBL at *Kundasale* indicating the importance of site specific fertilizer recommendations. Yield increments observed in the treatments by providing of deficient nutrients other than N, P and K showed the necessity of supplying site specific fertilizer recommendation for each soil. Investigations leading to evaluation of crop specific critical values for plant nutrients could further refine this site specific fertilizer recommendation procedure.

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