OPENING MINDS:
RESEARCH FOR SUSTAINABLE
DEVELOPMENT

# Impact of Excessive Use of Phosphorus Fertilizer on Soils in the Central Highlands of Sri Lanka and Possible Health Hazards

Partlee Samarakody, C.S. De Silva*

*The Open University of Sri Lanka, Nugegoda, Sri Lanka*

**Corresponding author: Email: csdes@ou.ac.lk*

## 1 INTRODUCTION

Phosphorus (P) is one of the nutrients essential for plant growth. The total amount of P in an average mineral soil is much lower than nitrogen, potassium, calcium or magnesium and is in the range of 0.02 to 0.15% P (Mengel and Krik, 1982). However it is a fact that most of the phosphorus present in the soil is not immediately available to plants. When a soluble source of this element is supplied to soils in the form of fertilizers, phosphorus is often fixed or rendered insoluble, and may not be available to higher plants, even under the most ideal field conditions (Brady, 1990). Plant roots take up nearly all phosphorus as either the primary or secondary orthophosphate anion ($H_2PO_4^-$, $HPO_4^{-2}$). Primary orthophosphate is the form that is dominant in acid soils and is taken up about 10 times as readily as the secondary orthophosphate form.

Long term continuous application of P fertilizers and other P sources such as organic wastes and manure cause P accumulation in the surface horizon (Zhang et al., 2004). The majority of Sri Lankan farmers apply more than the recommended quantity of fertilizer (National Science Foundation, 2000) aiming for higher economical benefits. Therefore in agricultural soils when high quantities of phosphorus are received, available P content exceeds the critical P for fertilizer response in this situation. Soil P has become more of an environmental concern than an agronomic concern in areas with intensive cropping and livestock production (Central Environmental Authority, 1995; Sharply et al, 1995). High concentration of phosphorus has adversely affected the environment, animals, and humans. High concentrations of phosphorus in water cause "Eutrophication" leading to death of fish in water (Arnao, 1995). Therefore the aim of this study is to estimate the total, organic, inorganic and available phosphorus levels in the central high lands (Badulla, Bandarawela, Welimada and Nuwara Eliya) where intensive vegetable cultivation is taking place with the heavy use of organic and inorganic fertilizers and suggest possible mitigation measures to avoid health hazards.

## 2 METHODOLOGY

### 2.1 Sampling methods

Thirty four composite (34) soil samples, seventeen (17) from surface and seventeen (17) from sub surface representing four (Badulla, Bandarawala, Walimada and Nuware Eliya ) vegetable growing soil series in up country wet zone and up country intermediate zones of Sri Lanka were collected. These sites were all in

vegetable holdings where fertilizer has been added for a long time. Surface soil samples were taken from the depth of 0-20cm and subsurface soil samples were taken from the depth of 20-40 cm from the same selected fields. Each composite sample was prepared after taking 34 samples from the four locations mentioned above. Soil samples were air dried at room temperature and crushed to pass through a 2-mm sieve to remove coarse fragments and then stored in tightly sealed plastic bottles until analyses were conducted.

### 2.2 Soil analysis

Seventeen surface soil samples and seventeen sub surface soil samples were analyzed for physical and chemical properties (Soil pH, Electrical conductivity, Available P, Exchangeable K, Organic matter (%) and total available phosphorus). Available P was determined by extraction with distilled water, Bray and Kurtz No. 1, Morgan' extraction, Olsen's, Mehlich 3 and Mehlich 1. Phosphorus in the extract was determined colorimetrically by the molybdenum blue method as modified by Murphy and Riley (1962). pH and electrical conductivity (EC) was measured by pH meter.

## 3 RESULTS AND DICUSSION

### 3.1 Soil properties

Particle size analysis indicates that all the soils were sandy clay loam; all soils contained high amount of clay and low amount of sand (Table 1). The pH values for the up country vegetable growing soils ranged from 3.96 to 5.89 at soil depths (0 to 20 cm). The soil pH is generally influenced by several management factors including the crop grown, irrigation, and the type of fertilizer used. The soils were generally acidic. The EC values ranged from 69.3-800µs. All the soils were generally high in EC. The observed organic matter values of the soils ranged from 0.82 – 11.40%. Badulla and Bandarawela soils showed the same pattern of the organic matter contents. Walimada and Nuwara Eliya soils showed the same pattern. But in Walimada and Nuwara.Eliya soils the organic matter content was higher than that of the Badulla and Bandarawella soils. Exchangeable K cations were generally high. This is due to the low clay and organic-matter contents (De Alwis and Panabokke, 1972-1973).

Particle size analysis indicated that the sub surface soils were generally sandy clay loam; some soils in Nuwara Eliya and Bandarawela were sandy clay. All the sub surface soils had a high amount of clay. The pH values for the up country vegetable growing soils ranged from 3.59 to 5.61 at soil depths (20 to 40 cm). The surface and subsurface soils were found to be generally acidic. The EC values ranged from 47.9-541µs. All the sub surface soils were extremely high in EC. But lower than the top soil. The exchangeable K values ranged from 60.79 – 486.32ppm. Exchangeable K was also high in sub surface soils, but lower than the surface soils. The observed organic matter values of the soils ranged from 0.25 – 7.05%. Organic matter contents were found to be higher in the 0-20 cm depth than in the 20-40 cm depth.

### 3.2 Available P

The observed available P values of the surface soil ranged from 25.48 – 429.8ppm. Available P in the surface soil of Nuwara Eliya ranged from 321-429 ppm which was extremely high and exceeded the safe limit of 30-40ppm of the World health Organization (WHO). Major plant nutrients, especially P content in poultry manure, were higher than in the other organic manures (Maraikar and Amarasiri, 1988). Farmers in Nuwara Eliya use large amounts of poultry manure together with high rates of chemical fertilizers. Wijewadena (1999) reported


ISSN 2012-9916 © The Open University of Sri Lanka

that the combined use of organic and chemical fertilizer more effectively increased the major plant nutrients in the soils of the up country vegetable cultivations. This may be the reason for the higher available P in Nuwara Eliya soils.The observed available P values of the sub surface soil ranged from 19.07 – 306.54ppm. Available P contents were also higher in these soils but lower than that of the surface soils. Available P, exchangeable K and organic matter content of sub-surface soils from Nuwara Eliya were higher than those of the other soil series (19-306ppm) but lower than that of the top soil.

## 3.3 Total P

Total P content in the soils ranged from 1108.46 to 4587.31 ppm of the surface soils with mean values of 1302.82, 1455.21, 1364.26 and 2878.58 ppm in Badulla, Bandarawella, Walimada and Nuwara-Eliya soils respectively. The positive correlation of total P with organic carbon showed that organic carbon contributes significantly towards the total P content. Total P was correlated negatively with percentage sand but positively with percentages of silt, clay and organic carbon. This indicated that the P in soils is mostly concentrated in the finer fractions of the soil, probably because of the high fixation of P and Fe and Al hydrous oxides and Kaolinite in the clay and silt fractions.

## 3.4 Organic P

Organic P content of the soil ranged from 133.29 to 1664.44ppm with mean values of 199.82, 332.93, 399.47 and 1051.93ppm in Badulla, Bandarawella, Walimada and Nuwara-Eliya soils respectively. These values exceed the safe limit of WHO. This constituted 20, 23, 29 and 36% of the total P in the four series of soils. Long term continuous application of P fertilizers and other P sources such as organic wastes and manure cause P accumulation in surface horizon. (Zhang et al, 2004). Total, inorganic and organic P was highest in Nuwara Eliya soil samples as shown in Figure 1.

## 3.5 Organic matter (%)

Soils in Nuwara Eliya has the highest Organic matter content and this may be due to the heavy use of poultry and organic manure for the-country vegetable cultivation. Organic matter percentage ranges in between 9 to 11.4ppm.

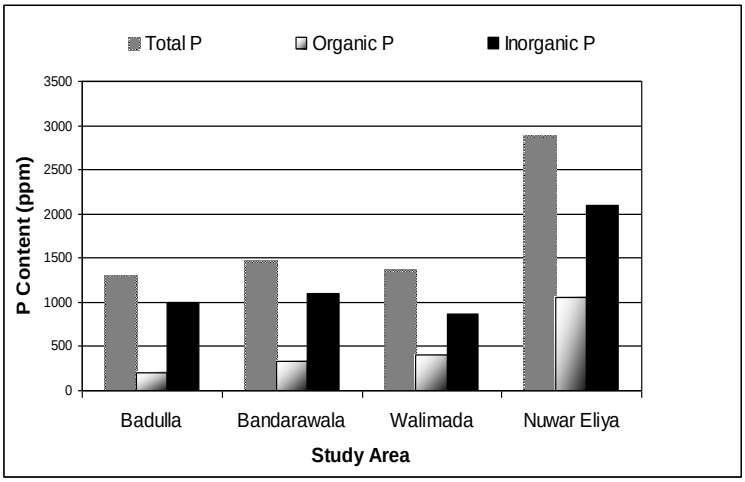


**Figure 1:** Distribution of Total, Organic and Inorganic P factions in four Study areas

**Table 1:** Physio chemical properties of soil (surface soil)

| No | Name of the soil series | Texture | Soil pH | EC (µs) | OM (%) | Total P (ppm) | Organic P (ppm) | Inorganic P (ppm) | Available P (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Badulla | Scl | 4.85 | 75 | 2.94 | 1338.0 | 133.3 | 1186.8 | 127.5 |
| 2 | Badulla | Scl | 3.96 | 69.3 | 2.35 | 1126.8 | 166.5 | 849.2 | 25.91 |
| 3 | Badulla | Scl | 5.24 | 80.1 | 1.19 | 1443.7 | 299.7 | 943.3 | 130.5 |
| 4 | Bandarawella | Scl | 4.81 | 243 | 3.49 | 1159.6 | 233.1 | 1204.9 | 180.3 |
| 5 | Bandarawella | Scl | 4.25 | 51.3 | 1.53 | 1313.1 | 332.9 | 962.1 | 151.2 |
| 6 | Bandarawella | Scl | 5.51 | 127.1 | 2.35 | 1892.9 | 432.8 | 1110.2 | 242.9 |
| 7 | Walimada | Scl | 4.25 | 237 | 1.65 | 1534.8 | 599.2 | 929.8 | 164.2 |
| 8 | Walimada | Scl | 4.12 | 107.6 | 2.94 | 1534.8 | 466.1 | 1016.2 | 125.5 |
| 9 | Walimada | Scl | 4.89 | 187.1 | 0.82 | 1126.8 | 166.5 | 663.1 | 25.48 |
| 10 | Walimada | Scl | 5.89 | 79.8 | 3.06 | 1347.2 | 532.6 | 794.2 | 145.7 |
| 11 | Walimada | Scl | 4.52 | 249 | 3.26 | 1108.5 | 299.6 | 683.1 | 153.4 |
| 12 | Walimada | Scl | 4.4 | 800 | 6.76 | 1534.8 | 332.8 | 1149.9 | 224.6 |
| 13 | N.Eliya | Scl | 4.05 | 89.3 | 9.92 | 1637.1 | 466.0 | 721.8 | 360.6 |
| 14 | N.Eliya | Scl | 5.72 | 289 | 5.17 | 3598.2 | 299.6 | 1606.1 | 338.0 |
| 15 | N.Eliya | Scl | 4.48 | 758 | 1.00 | 3785.8 | 1165.1 | 2597.7 | 429.8 |
| 16 | N.Eliya | Scl | 5.62 | 244 | 9.02 | 4570.3 | 1664.4 | 2877.2 | 321.8 |
| 17 | N.Eliya | Scl | 5.37 | 779 | 11.4 | 4587.3 | 1664.4 | 2706.9 | 360.6 |

Scl-Sandy Clay Loam

## 4 CONCLUSIONS AND RECOMMENDATIONS

The results of the study showed that soil supporting vegetable cultivations in up country of Sri Lanka were generally high in total as well as the organic forms of P. Nuwara-Eliya soils showed high total P and Organic P than other soils and exceeds the safe limit of 30-40 ppm according to World health Organization. Although soils of Badulla had lowest amounts of total P and organic P fractions other two series (Walimada and Bandarawela) showed moderate amounts. Therefore farmers are advised to do a soil test for available phosphorus before fertilizer application in order to minimize the groundwater pollution. As of now the quick and easy method of a field tool kit is available to measure the phosphorus content in soil and farmers are strongly advised to contact the nearest Department of Agriculture.

### Acknowledgement

Authors acknowledge Dr P. Weerasinghe and other staff members of Horticulture Crop Research and Development Institute, Gannoruwa, Peradeniya for offering the opportunity to conduct the research.


*ISSN 2012-9916 © The Open University of Sri Lanka*

## REFERENCES

Anjana,S., Shahid UMAR and Muhammad, I.(2007) - Nitrate accumulation in plants, factors affecting the process, and human health implications. A review, Agron. Sustain. Dev. 27 (2007) 45–57

Brady, N.C. (1990). The nature and properties of soils. Mcmillon publishing inc. New York.

Black, CA. and Goring, CA. I. (1953). Soil and Fertilizer Phosphorus in Crop Nutrition (ed. W.H. Pierre and A.G. Norman). New York Academic Press. 10th Edition

Bray, R.H. and Kurtz, L.T. (1945). Determination of total, organic and available forms of phosphorus in soils. Soil Science, 59, 39-45.

Koralage, I. S. A., P. Weerasinghe, N. R. N. Silva and C. S. De Silva (2015).The Determination of Available Phosphorus in Soil: A Quick and Simple Method. OUSL Journal Vol 8:1-18

Zhang, Q., M.R. Alfarra, D.R. Worsnop, J.D. Allan, H. Coe, M.R. Canagaratna, and J.L. Jimenez (2005). Deconvolution and Quantification of Hydrocarbon-like and Oxygenated Organic Aerosols Based on Aerosol Mass Spectrometry. Environmental Science and Technology, 39: 4938-4952, 2005, doi: 10.1021/es048568l.