

Phosphorus Status of Major Coconut Growing Soils of Sri Lanka on the performance of *Pueraria phaseoloides*

D. M. D. I. Wijebandara,

Soils & Plant Nutrition Division, Coconut Research Institute, Lunuwila 61150, Sri Lanka
iraniew@gmail.com

ABSTRACT :

Phosphorus status of major coconut growing soils in the Intermediate Zone of Sri Lanka on the growth parameters and root nodulation of *Pueraria phaseoloides* was studied in plant house and field experiments. In the plant house experiment, *Pueraria phaseoloides* was planted in Non Calcic Brown, Red Yellow Podzolic, Sandy Regosols, Yellow Latosols and Alluvial soils treated with phosphorus at the rate of 1g of Triple Super Phosphate (TSP) per pot (T_1) along with a control (T_0 -no TSP) treatment. In the field experiment, *Pueraria phaseoloides* was grown on above soils with application of Eppawela Rock Phosphate (ERP) at the rate of 912 kg ha⁻¹ (T_1) along with a control (T_0) treatment. The relationships between the relative increase of each crop parameter (X) due to phosphate treatment, which is defined by $[T_1(X) - T_0(X)] / T_0(X)$ and the initial available soil phosphorus determined by the 2.5 % Acetic acid and Olsen's bicarbonate were studied. The critical level for available soil phosphorus was determined by fitting the data in above relationships to the Cate and Nelson model. The results of the pot experiment showed that *Pueraria phaseoloides* significantly responded to P fertilizer application on soils containing available phosphorus less than 5 mg kg⁻¹ in both extraction methods. In the field experiment, the limiting value of soil phosphorus was 10 mg/kg⁻¹ as determined by 2.5 % acetic acid and 9 mg kg⁻¹ as determined by Olsen's method. Results revealed that the inherent phosphorus levels of most of the coconut growing soils in the Intermediate zone were below the limiting values and phosphate fertilizer application to *Pueraria phaseoloides* is essential to enhance its growth and root nodulation.

Key words : coconut growing soils, critical level, growth parameters, *Pueraria phaseoloides*, relative increase, root nodulation, soil phosphorus

INTRODUCTION :

Pueraria phaseoloides is an important leguminous cover crop grown in coconut lands to control soil erosion, suppress weed growth, increase soil moisture, recycle nutrients, increase soil nutrient availability, organic matter and improve soil fertility by fixing atmospheric

nitrogen. Well grown *Pueraria phaseoloides* creepers would provide an effective soil cover and high nodulation of roots that would enhance nitrogen fixation. Nitrogen accumulation in aboveground biomass of *Pueraria phaseoloides* is 8 to 14 times higher than in intercropped fruit

trees (Lehmann *et al.*, 2000). Nutrient re-cycling may be significantly enhanced by the cover crop, leading to less nutrient leaching and higher nutrient contents, such as K, in the topsoil. The amount of biological N fixation is an important factor for the N cycling. As a result, total soil N contents may often increase and enhance N availability is enhanced. The nutrient re-cycling depends on biomass production, nutrient content and decomposition rate. Lehmann *et al.*, 1999b reported that proportion of N accumulation in the above ground biomass of *Pueraria phaseoloides* was 83 % due to its high N content in a mixed fruit tree cropping system. He further stated that proportion of biomass production (55 %) and N - turnover (66 %) of *Pueraria phaseoloides* is also very high in comparison to fruit trees. Due to the high N contents and the low C/N ratio, litter decay is usually very rapid.

The soils in the coconut growing areas of Sri Lanka are generally deficient in the active as well as available forms of P (Loganathan *et al.*, 1982; Wijebandara and Somasiri, 1994). In some experiments carried out in Sri Lanka, particularly with soils containing lateritic gravels (Ultisols), coconut palms showed positive response to P fertilizer application (Balakrisnamurti, 1972; Nethsinghe, 1963; Salgado, 1957). But in other countries such as Philippines (Magat, 1979; Prudent and Mendoza, 1976), Tanzania (Thomas and Nandra, 1973), Jamaica (Smith, 1969) and Malaysia (Kanapathy, 1976) no response was obtained for P fertilizer application to coconut palms indicating the sufficiency of available P. However, phosphorus deficiency symptoms are not commonly observed in coconut plantations of Sri Lanka irrespective of soil and climate factors.

In certain coconut growing areas of Sri Lanka, *Pueraria phaseoloides* cannot be successfully grown as a cover crop. Establishment and maintenance of *Pueraria phaseoloides* on sandy soils in dry areas is difficult due to moisture stress in the top soil. Although *Pueraria phaseoloides* can be grown well as a cover crop in coconut lands in the wet areas, yet, it has been found that the root nodulation in those plants is poor. However, *Pueraria phaseoloides* cultivation as a cover crop in coconut lands of Sri Lanka is carried out without phosphate fertilizer application although it is known that phosphate deficiency in soils could adversely affect the growth of *Pueraria phaseoloides* and root nodulation. The lack of P affects both nodule formation and functioning and may become a limiting factor in some tropical soils (Appaduarai, 1968). Under tropical conditions application of 100 kg of Super Phosphate resulted in the fixation of 76 additional pounds of nitrogen (Vincent, 1965). Different rock phosphate sources increased dry matter yield, nodulation and P uptake of *Pueraria phaseoloides* compared with controls (Crespo and Curbelo, 1990, George and Sudhakumari, 1997, Varghese and Ama, 1991). The objective of the present study was to study the effect of soil P status of different coconut growing soils of Sri Lanka on growth characteristics and root nodulation of *Pueraria phaseoloides*.

MATERIALS AND METHODS :

A green house pot experiment was carried out using eight soil series comprising three from the coastal plain, two from an alluvial flood plain and three from the mantled plain collected from different locations of IL1 (semi-wet Intermediate Low country region) IL3 (semi

Table 1: Land form, great soil group and soil series of soils used for the pot experiment

| Land Form | Great Soil Group | Soil series |
|----------------|---|-------------------|
| Mantled Plain | Non Calcic Brown (NCB) | Tambarawa (TAM) |
| Mantled Plain | Red Yellow Podzolic (RYP) | Andigama (AND) |
| Mantled Plain | Red Yellow Podzolic (RYP) | Kurunegala (KUR) |
| Coastal Plain | Sandy Regosols | Weliketiya (WEL) |
| Coastal Plain | Latosols and Regosols on old red and yellow sands | Madampe (MDP) |
| Coastal Plain | Latosols and Regosols on old red and yellow sands | Rathupasa (RAT) |
| Alluvial Plain | Alluvial soils | Welipelessa (WEP) |
| Alluvial Plain | Alluvial soils | Palugaswewa (PAL) |

(Source- Somasiri *et al.*, 1994)

– dry Intermediate Low country region) agro-ecological regions of Sri Lanka. The land form and great soil group of each soil series is given in (Table 1).

Soil samples were taken from both A and B master horizons of each soil series for the pot experiment. Soils were passed through 6 mm sieve at their field moist state soon after sampling and sub samples were taken from each soil for chemical analysis for available P and other chemical properties. Each soil sample was filled into four polypropylene pots (1.5 L) and each was treated with Triple Super Phosphate (TSP, 46 % P_2O_5) at the rate of 1 g per pot (T_1) along with a control (no phosphate) (T_0), in duplicate. Each soil was treated with a basal dose of N at the rate of 0.16 g Ammonium Sulphate ($[(NH_4)_2SO_4]$, 20.6 % N), K at the rate of 0.2 g Muriate of Potash (MOP, 60 % K_2O) and Mg at the rate of 0.1 g Magnesium Sulphate ($MgSO_4$, 27 % MgO) per pot. After treatment application, pots were arranged in a complete randomized design inside a green

house and four pre-germinated *Pueraria phaseoloides* seedlings were planted in each pot. The pots were watered daily to maintain soil moisture content at the 60 % of the field capacity. Counting of *Pueraria phaseoloides* leaves, commenced one month after planting and continued at two week intervals for three months. The pots were dismantled, four months after planting and fresh weight, dry weights of vegetative parts and number of live nodules in the roots were recorded.

A field experiment was carried out in five soil series found in Bandirippuwa estate, Lunuwila that is located in North-Western province of Sri Lanka. The land form and great soil group of each soil series is given in (Table 2). Beds of dimension 1.5 m x 1.5 m were prepared with the top soil (A horizon) and the sub soil (after removal of A horizon) of each soil series separately. Soil samples were taken from each bed for chemical analysis. The beds were treated with ERP (30 % P_2O_5) at the rate of

Table 2: Land form, great soil group and soil series of soils used for the field experiment

| Land form | Great Soil Group | Soil Series |
|----------------|---|----------------|
| Mantled plain | Red Yellow Podzolic (RYP) | Boralu (BOR) |
| Mantled plain | Red Yellow Podzolic (RYP) | Pallama (PLM) |
| Coastal plain | Latosols and Regosols on old red and yellow sands | Madampe (MDP) |
| Coastal plain | Regosols | Sudu (SUD) |
| Alluvial plain | Alluvial soils | Lunuwila (LUN) |

(Source- Somasiri *et al.*, 1994)

912 kg ha⁻¹ (TF₁) alone with a control (without phosphate) (TF₀). All the beds were treated with a basal dose of N at the rate of 95 kg ha⁻¹ of (NH₄)₂SO₄ (20.6 % N), K at the rate of 119 kg ha⁻¹ of MOP (60 % K₂O) and Mg at the rate of 60 kg ha⁻¹ MgSO₄ (27 % MgO). Treatments were arranged in a completely randomized block design with three replicates and planted with equal number of pre germinated *Pueraria phaseoloides* seedlings in each bed.

Three months after planting vegetative parts of *Pueraria phaseoloides* in a sample area of 0.5 m² were harvested and fresh and dry weights of harvested materials were recorded. Initial soils were analysed for pH at 1:5 soil: water ratio (Michael, 1965), Organic matter by Walkley and Black method (Jackson, 1967), total N by Kjedhal method (Black, 1965), texture by pipette method (Day, 1965), phosphorus by 2.5 % Acetic acid method (Anon, 1985) and Olsen's bicarbonate method (Olsen *et al.*, 1954).

RESULTS AND DISCUSSION :

As seen from Tables 3 and 4, bi-carbonate extractable P fraction of the soils used for the pot experiment and the field experiment ranged

from 2.48 to 29.5 mg kg⁻¹ and 4.19 to 22.4 mg kg⁻¹ respectively. The 2.5 % Acetic acid extractable P fraction of the soils of the pot experiment ranged from 2.38 to 28.3 mg kg⁻¹ while that of the field experiment ranged from 3.80 to 101.0 mg kg⁻¹. The Acetic acid extractable P contents in pot experiment were found to be low (2.38 - 3.04 mg kg⁻¹) in soils having clay fraction more than 17.5 % (Andigama series and Kurunegala series) compared to the other soils which contained more than 74.8 % sand, less than 19.1 % clay and silt (Table 3). It indicated that the acid soluble P fractions, mainly apatites, were low in those soils that contained higher clay fraction compared to those that contained higher sand fraction. However, Olsen's bicarbonate-P values, which depend on basic calcium bound P compounds, did not show the same trend. Generally, apatites are not readily dissolved in alkaline extractants such as NaHCO₃ and therefore the latter extracts a different P fraction. According to the classification of Trough (1948), 50 % of soils used for the pot experiment were acidic (pH 4.5 to 5.5) while the rest of the soils were slightly acidic (pH 5.5 to 5.9) and the soils used for the field experiment were acidic (Table 3 and 4). However, a significant relationship

Table 3: Important chemical and physical properties of soils used for the post experiment

| Soil series | PH - (1:5 H ₂ O) | Total N (mg kg ⁻¹) | O.M % | Texture | | | 2.5 % HAc- P (mg kg ⁻¹) | Olsen's - P (mg kg ⁻¹) |
|-------------|-----------------------------|--------------------------------|-------|----------|----------|----------|-------------------------------------|------------------------------------|
| | | | | Sand (%) | Silt (%) | Clay (%) | | |
| TAM-A | 5.35 | 292 | 0.47 | 89.0 | 3.65 | 4.10 | 4.77 | 4.01 |
| TAM-B | 5.44 | 292 | 0.34 | 87.0 | 4.08 | 3.95 | 3.34 | 3.18 |
| AND-A | 5.90 | 1058 | 1.27 | 60.3 | 8.40 | 26.6 | 2.60 | 2.99 |
| AND-B | 5.79 | 693 | 0.98 | 60.0 | 8.43 | 27.8 | 2.38 | 2.48 |
| KUR-A | 5.03 | 547 | 1.40 | 74.1 | 5.85 | 17.5 | 3.04 | 4.90 |
| KUR-B | 4.99 | 547 | 0.81 | 71.2 | 5.28 | 18.6 | 2.70 | 3.21 |
| WEL-A | 5.18 | 292 | 0.22 | 94.5 | 1.85 | 3.38 | 6.40 | 6.62 |
| WEL-B | 5.12 | 182 | 0.11 | 89.2 | 3.90 | 2.03 | 4.07 | 3.95 |
| MAD-A | 5.73 | 328 | 0.45 | 90.0 | 3.63 | 2.10 | 3.85 | 3.50 |
| MAD-B | 5.19 | 182 | 0.22 | 87.4 | 4.95 | 3.40 | 4.56 | 3.18 |
| RAT-A | 5.67 | 292 | 0.34 | 92.5 | 4.08 | 2.75 | 10.0 | 7.38 |
| RAT-B | 5.67 | 265 | 0.24 | 93.7 | 3.78 | 2.15 | 6.86 | 6.24 |
| WEP-A | 5.33 | 379 | 0.34 | 87.5 | 4.15 | 3.98 | 5.19 | 5.38 |
| WEP-B | 5.76 | 455 | 0.29 | 87.9 | 6.58 | 1.85 | 4.57 | 2.73 |
| PAL-A | 5.55 | 303 | 0.25 | 88.4 | 3.80 | 3.98 | 28.3 | 14.9 |
| PAL-B | 5.78 | 379 | 0.28 | 74.8 | 11.25 | 7.90 | 26.2 | 29.5 |

A - A horizon B - B horizon

between soil pH values and bi-carbonate extractable P or Acetic acid extractable P values was not found for these soils.

As seen from Tables 3 and 4, most of the soils used for the experiment were low in both total nitrogen (< 500 mg kg⁻¹) and organic matter content (< 1 %). Therefore, it is essential to improve organic matter content and increase available nitrogen and phosphorus quantities to enhance the agricultural productivity of these soils. It could be achieved by incorporating *Pueraria phaseoloides* into the soil. However, apart from vegetative growth, nodulation in roots is an important factor for effective nitrogen fixation of *Pueraria phaseoloides*.

In the pot experiment, the values of total dry matter weight, the number of leaves

and the number of root nodules of *Pueraria phaseoloides* showed a significant increase in response to P fertilizer application to soils. To report the response of any crop parameter (X) to P fertilizer application, the term Relative Increase (RI) defined as $T_1(X) - T_0(X) / T_0(X)$, where $T_1(X)$ is the crop parameter of T_1 or TF_1 and $T_0(X)$ is that of T_0 or TF_0 , has been used in this paper. $RI > 0$ indicates a positive response in parameter (X) of *Pueraria phaseoloides* to TSP application and $RI > 1$ indicates a higher positive response.

Table 4 : Important chemical and physical properties of soil in field experiment

| Soil series | PH - (H ₂ O) | Total N (mg kg ⁻¹) | O.M (%) | Texture | | | 2.5% HAe-P (mg kg ⁻¹) | Olsen's - P (mg kg ⁻¹) |
|-------------|-------------------------|--------------------------------|---------|----------|----------|----------|-----------------------------------|------------------------------------|
| | | | | Sand (%) | Silt (%) | Clay (%) | | |
| BOR-A | 4.86 | 890 | 1.76 | 77.8 | 17.0 | 3.45 | 101.0 | 22.4 |
| BOR-B | 4.34 | 525 | 1.12 | 78.2 | 10.9 | 4.58 | 5.75 | 8.23 |
| PLM-A | 5.19 | 470 | 0.97 | 85.5 | 7.08 | 3.40 | 82.4 | 4.19 |
| PLM-B | 4.83 | 336 | 0.63 | 87.1 | 8.50 | 3.28 | 13.2 | 9.76 |
| MDP-A | 5.32 | 265 | 0.47 | 94.5 | 2.78 | 3.10 | 7.82 | 7.47 |
| MDP-B | 5.23 | 220 | 0.33 | 88.4 | 30.3 | 3.90 | 3.80 | 4.53 |
| SUD-A | 5.09 | 377 | 0.90 | 97.7 | 1.58 | 3.45 | 6.94 | 6.81 |
| SUD-B | 5.01 | 345 | 0.68 | 93.5 | 2.53 | 3.03 | 5.12 | 8.47 |
| LUN-A | 5.32 | 291 | 0.53 | 94.6 | 0.90 | 2.68 | 7.42 | 13.2 |
| LUN-B | 5.27 | 235 | 0.36 | 97.6 | 1.35 | 2.80 | 8.10 | 14.7 |

A - A horizon, B - B horizon

Table 5: Relative Increase (RI) of dry matter weight of vegetative parts, number of nodules and number of leaves of *Pueraria phaseoloides* used for the pot experiment

| Soil series | RI of Dry matter | RI of Number | RI of Number |
|-------------|----------------------------|--------------|--------------|
| | weight of vegetative parts | of nodules | of leaves |
| TAM-A | 1.33 | 2.81 | 0.61 |
| TAM-B | 3.99 | 3.56 | 0.86 |
| AND-A | 10.5 | 14.3 | 1.02 |
| AND-B | 31.3 | 46 | 1.81 |
| KUR-A | 1.65 | 5.88 | 0.71 |
| KUR-B | 12.3 | 34 | 0.75 |
| WEL-A | 0.85 | 0.44 | 0.44 |
| WEL-B | 3.33 | 9 | 0.73 |
| MAD-A | 4.25 | 7.05 | 1.45 |
| MAD-B | 5.16 | 8.38 | 0.98 |
| RAT-A | 0.25 | 0.71 | 0.34 |
| RAT-B | 0.67 | 3.76 | 0.21 |
| WEP-A | 9.72 | 6.11 | 1.08 |
| WEP-B | 17.9 | 25.7 | 1.85 |
| PAL-A | 0.20 | 0.63 | 0.28 |
| PAL-B | 0.37 | 0.65 | 0.31 |

A - A horizon, B - B horizon

The RI values of dry matter, number of nodules and the number of leaves were less than one for PAL-A, PAL-B, RAT-A and WEL-A soils but greater than one for the other soils (Table 5). This is a consequence of the latter soils being more deficient in available phosphorus than the former, and therefore *Pueraria phaseoloides* highly responded to TSP application on the latter soils. The foregoing results also showed that

vegetative growth as well as root nodulation of *Pueraria phaseoloides* increased by many fold as a result of phosphorus fertilizer application. The relationships between RI values and soil P values determined by the chemical methods showed that it is possible to obtain a limiting value of available soil P for vegetative growth as well as for nodulation of *Pueraria phaseoloides* which would be useful in planning P fertilizer application.

The relationship between RI of above mentioned crop parameters in the pot experiment and inherent available soil P determined by

each of the two chemical extraction methods showed a curvilinear relationships as shown in Figure 1 : (1a, 1b, 1c, 1d, 1e and 1f).

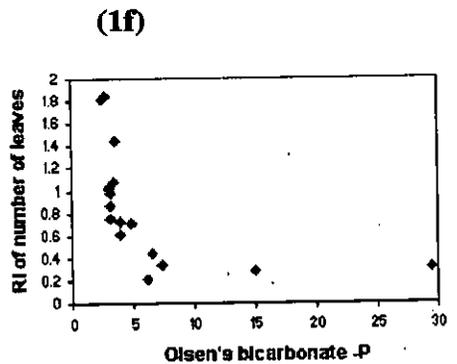
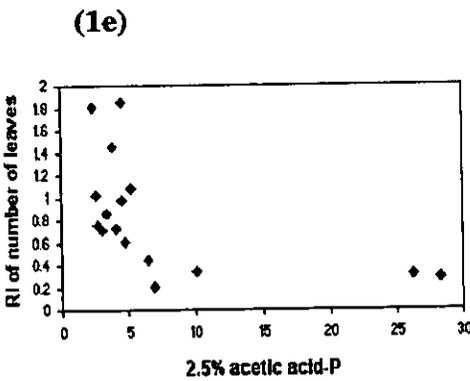
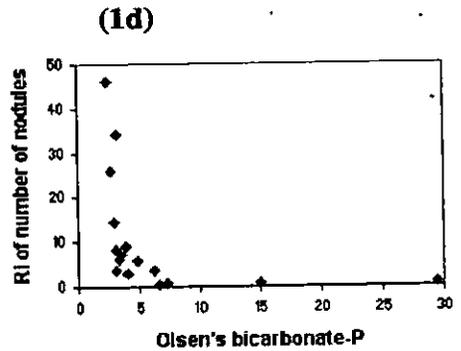
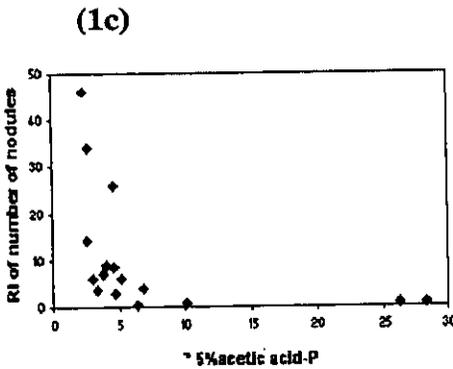
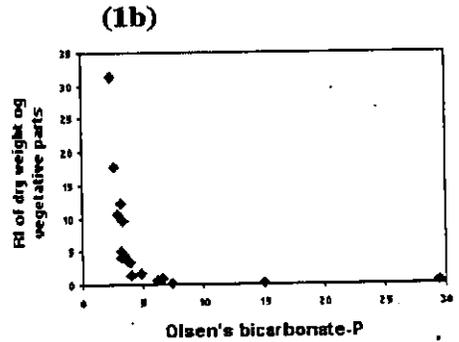
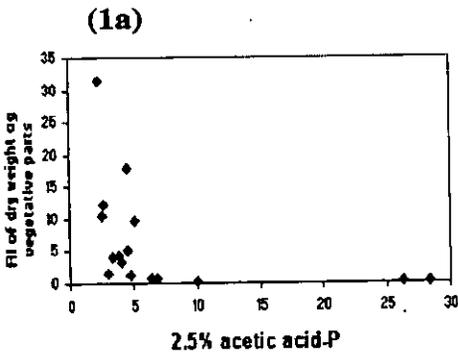


Figure 1 : Relationship between Relative Increase (RI) of different parameters and soil P by 2.5 % Acetic acid method and Olsen's bicarbonate method

Table 6 : Highest R² values and critical levels obtained by Cate and Nelson statistical procedure

| Soil P test | R ² | Critical level mg/kg ⁻¹ |
|---------------------|------------------|---------------------------------------|
| | Dry weight basis | |
| 2.5 % HAc | 0.836** | 5.1 |
| Olsen's bicarbonate | 0.703** | 4.9 |

*** P < 0.001, ** P < 0.01, * P < 0.05

The critical level for available soil P was determined by applying the Cate and Nelson (1965) statistical method to the above relationships. Cate and Nelson statistical model (Cate and Nelson, 1971) provides a method for determining the dividing line, or the critical level between two categories of soils; viz., high probability of response (low soil P status) and low probability of response (high soil P status) to applied P.

Each soil P data set (Table 3) was arranged in the ascending order with corresponding RI values for *Pueraria phaseoloides* (Table 5), and by a simple iterative process a series of R² values were obtained for arbitrary divisions into high and low P status, at various levels of soil P. The R² was calculated for each arbitrary division and the division at which R² becomes maximum is taken as the critical level of soil P for the particular soil-plant combination, with respect to the method tested. The value of R² is also an indication of the degree of fitness of the data set to the model. The calculated R² values, and the critical level for each soil P test are given in Table 6.

Acetic acid P values showed the higher correlation with Relative Increase of *Pueraria phaseoloides* fitting significantly to the Cate and Nelson model with R² of 0.836 (P < 0.01) for dry weight of vegetative parts. Thus the 2.5 %

HAc-P values could account for the variation of 83 % of the production of vegetative parts of *Pueraria phaseoloides* in different soils.

As seen from Figure 1 (1a, 1b, 1c, 1d, 1e and 1f) the RI values of all those crop parameters increased when both Olsen's bicarbonate P and 2.5 % Acetic acid - P in soils were less than 5.0 mg kg⁻¹. The RI values for dry matter weight, number of live nodules and number of leaves of *Pueraria phaseoloides* ranged between 0.2 to 9.72, 0.44 to 6.11 and 0.21 to 1.08 respectively when Olsen's bicarbonate P or 2.5% Acetic acid - P in the soil was greater than 5.0 mg kg⁻¹. On the other hand it ranged from 1.33 to 31.39 for dry matter weight, 2.81 to 46 for number of live nodules and 0.61 to 1.85 for number of leaves when Olsen's bicarbonate P or 2.5 % Acetic acid - P the soil was less than 5.0 mg kg⁻¹. It showed that soil P level of 5 mg kg⁻¹ was the critical level and P levels less than this value would provide higher growth response of *Pueraria phaseoloides* to TSP application in such soils.

There was a logarithmic relationship between the number of root nodules of *Pueraria phaseoloides* in control pots and the available soil P, determined by the each method (Figure 2a and 2b). The R² value of the logarithmic function for Olsen's method was 0.795** whereas that for 2.5 % acetic acid was 0.816** which indicated that more than 75 % of the variation of root

nodulation could be explained by the logarithm of the soil test values of P. This relationship also indicates the importance of soil P status for improving root nodulation which in turn is linked to nitrogen fixation.

Thus it can be expected that the amount of nitrogen fixed by *Pueraria phaseoloides* on most of the soils used for the pot experiment would be low because their available P content was less than 5 mg kg⁻¹ compared to few soils of which available P content was more than 5 mg kg⁻¹.

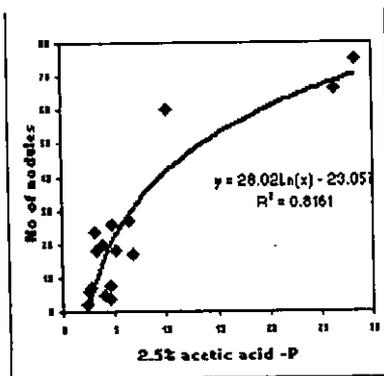
The soils that contained high concentration of available P (>5 mg kg⁻¹) such as Rathupasa series, Weliketiya series, Welipelessa series and Palugaswewa series soils represented only a small portion of the coconut growing area. The other soils that contained available P content less than 5 mg kg⁻¹ represented about 70 % of the major coconut growing areas of Sri Lanka.

Hence, the results of this experiment imply that phosphorus fertilizer application

is necessary for cultivation of *Pueraria phaseoloides* on major soils of the coconut growing areas, eg; Tambarawa series, Andigama series, Kurunegala series, and Madampe series because of their low available phosphorus content.

The same experiment was conducted in the field, on five soil series to test the extent of response of *Pueraria phaseoloides* to phosphorus treatment and to calibrate the soil test for determination of critical level in the field condition. However, RI values for vegetative parts of *Pueraria phaseoloides* in the field experiment were very much lower compared to that in the pot experiment (Table 7). The RI values on Pallama series (PAL-A and B) and Boralu series (BOR-A only) were as low as 0.04 -0.06. The RI values for vegetative parts of *Pueraria phaseoloides* on the other soils could be considered as the high response category because the values ranged from 0.181 to 1.00. The 2.5 % acetic acid P values for the same soils ranged from 3.80 to 8.10 mg kg⁻¹. However the range of Olsen's bicarbonate P values was 4.19 to 14.7 mg kg⁻¹.

(2a)



(2b)

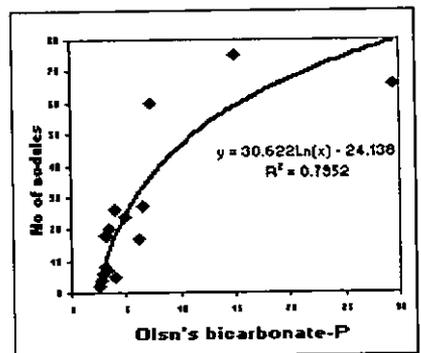


Figure 2: Relationship between soil P values of 2.5 % acetic acid extraction and Olsen's bicarbonate and number of nodules

Table 7: Relative Increase (RI) values of dry matter weight of *Pueraria phaseoloides* used for the field experiment

| Soil Series | RI of dry matter weight of vegetative parts |
|-------------|---|
| BOR - A | 0.040 |
| BOR - B | 0.252 |
| PLM - A | 0.047 |
| PLM - B | 0.062 |
| MDP - A | 1.000 |
| MDP - B | 0.342 |
| SUD - A | 0.682 |
| SUD - B | 0.474 |
| LUN - A | 0.181 |
| LUN - B | 0.215 |

A-A horizon, B-B horizon

The relationships between RI of the weight of vegetative parts of *Pueraria phaseoloides* in the field experiment and inherent soil P determined by the two chemical extraction methods are shown in Figure 3: (3a & 3b). The 2.5% acetic acid -P values showed a better relationship between the decreasing P value and increasing RI ratio than the Olsen's bicarbonate P.

The critical value of soil test P, which can be used to identify the P deficiency category of soils was obtained by applying Cate and Nelson method to the above relationships.

The calculated R^2 values for field data, and the critical level for each soil P test are given in Table 8. Acetic acid P values showed higher correlation with Relative Increase of *Pueraria phaseoloides* fitting significantly to the Cate and Nelson model with R^2 of 0.792 ($P < 0.01$) for dry weight of vegetative parts. Thus the 2.5 % HAC-P values could account for the variation of 79 % of the production of vegetative parts of *Pueraria phaseoloides* in different soils.

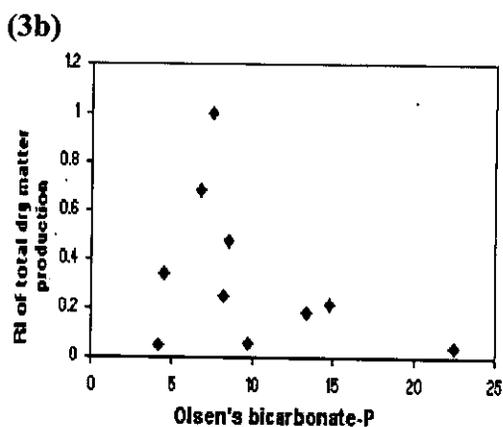
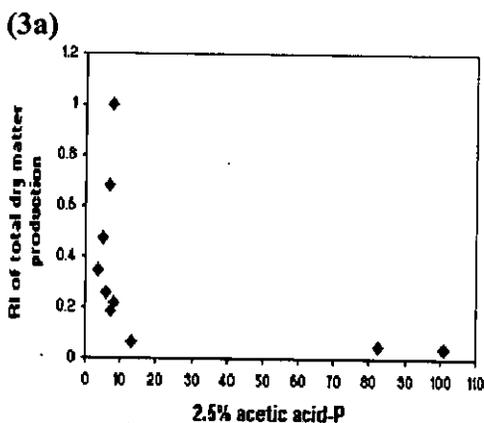


Figure 3: Relationship between Relative Increase (RI) of total dry matter content and soil P extracted by 2.5% acetic acid and Olsen's bicarbonate

Table 8 : Highest R^2 values by Cate and Nelson statistical procedure for the correlation between soil P by different methods and RI of dry weight of vegetative parts of *Pueraria phaseoloides* in field experiment

| Soil P test | R^2 | Critical level mg kg ⁻¹ |
|---------------------|---------|---------------------------------------|
| 2.5 % HAc | 0.792** | 10 |
| Olsen's bicarbonate | 0.670** | 9 |

*** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$

The 2.5 % Acetic acid P values fitted to Cate & Nelson model better than the Olsen's bicarbonate P. It was somewhat difficult to decide the critical value for Olsen's bicarbonate P from the results of the field experiment because of the scatter of points (Figure 3b). Moreover, the critical values determined from pot experiment and field conditions were different. Also, under field conditions, 2.5 % Acetic acid method proved to be more suitable than the Olsen's method for determination of a laboratory index.

The results showed that the growth response of *Pueraria phaseoloides* to phosphate fertilizer application on majority of soils was very high both in green house and field conditions. The results of the field experiment showed that dry matter production of *Pueraria phaseoloides* on seven soils out of ten (including A and B horizon of five soil series) significantly responded to ERP fertilizer application. According to the relationships between RI values and soil P values by the chemical methods, it became obvious that laboratory index for soil P, particularly by 2.5 % acetic acid method, could be adopted to determine the sufficiency or deficiency status

of soil P. Considering the limiting values for soil P derived from both the field and the pot experiments, 10 mg kg⁻¹ as determined by 2.5 % acetic acid method, could be taken as critical level for soil P for *Pueraria phaseoloides*. The critical level could be taken as 9 mg kg⁻¹ with respect to Olsen's bicarbonate method.

CONCLUSION

The results of the present study showed that the phosphorus levels of some coconut growing soils of Sri Lanka that were considered in this study are deficient for obtaining optimum benefits out of *Pueraria phaseoloides* cover crops in coconut lands such as effective ground cover and increased nodulation for nitrogen fixation. According to the results, the nodulation and vegetative growth of *Pueraria phaseoloides* can be enhanced significantly by phosphate fertilizer application to those soils. The sufficiency or deficiency status of soil phosphorus for *Pueraria phaseoloides* cultivation on these soils can be determined by 2.5 % acetic acid method or the Olsen's bicarbonate method. The critical levels for soil phosphorus by the two methods are 10 mg kg⁻¹ or 9 mg kg⁻¹.

REFERENCES :

- Aldaba, F. R. 1995. Coconut production in the Philippines: problem and prospects. *Plantations, Recherche, Development*, Sept-Oct: 15-18.
- Anon. 1985. Advisory soil analysis and interpretations bulletin 1. Macauley Institute for Soil Research and Scottish Agricultural Colleges Liason Group.p.4
- Appadurai, R. R. 1968. Grassland farming in Ceylon. Published by T. B. S. Godamunne & Sons Ltd. Kandy, Ceylon.
- Balakrisnamurti, T. S. 1972. Report of the Soil Chemistry Division (1971). *Ceylon Coconut Quarterly* 23, 30-44.
- Black, C. A. 1965. *Methods of soil analysis.2.* American Society. Of Agronomy Monography 9 2nd edn.
- Bunting, G. and J. N. Milsum. 1928. Cover crops and green manures. *Malayan Agric. J.* 16: 256-280.
- Cate, R. B. Jr and A. L. Nelson. 1965. A rapid method for correlation of soil test analyses with plant response data. *Int. Soil Testing Tech. Bull* No 1.
- Cate, R. B. Jr and A. L. Nelson. 1971. A simple statistical procedure for partitioning soil test correlation data into two classes. *Soil Sci. Soc. Am. Pro.*, 35, 658-660.
- Crespo, G. and Curbelo. 1990. Response to phosphorus of *Centrosema pubescens* and *Pueraria phaseoloides* in aluvisol soil of Pinar del Rio province (Cuba). *Cuban J. Agr. Sci.* 24(2):225-230.
- Day, P. R. 1965. Particle fractionation and particle size analysis. pp 545-567.
- George, E. S. and Sudhakumari. 1997. Response of *Pueraria phaseoloides* to direct and residual phosphorus from different sources. *Indian Journal of Natural Rubber Research* 10(1-2):113 - 115. {a} *Rubber Research Institute of India, Kottayam, KER, 686 009, India.*
- Jackson, M. L. 1967. *Soil Chemical Analysis,* Prentice Hall of India Private Limited, New Delhi.
- Kanapathy, K. 1976. Leaf analysis and fertilizers requirements of coconuts. *The Malaysian Agricultural Journal* 50, 322-339
- Lal, R., E. Regnier., E., D. J. Eckert., W. M. Edwards, and R. Hammond. 1993. Expectations of cover crops for sustainable agriculture. In; Hargrove, W. L. (Ed), *Cover crops for clean water.* Proc. Of the Soil and Water Conservation Society. pp. 1-11.
- Lehmann, J., Jr. Silva., da J. P. L. Trujillo, and K. Uguen. 2000. Legume cover crops and nutrient cycling in tropical fruit tree production. *Acta Horticulture* 531; 65-72.
- Lehmann, J., Jr. Silva., da J. P. G. Schroth, and da L. F. Silva. 1999b. Nitrogen use of mixed tree crop plantations with a legume cover crop. *Plant Soil.* 225 : (1-2) 63-72.
- Loganathan, P., P. M. N. Dayaratne, and R. T. Shanmuganathan. 1982. Evaluation of the phosphorus status of some coconut growing soils of Sri Lanka. *J. Agr. Sci., Camb.* 99, 25-33

- Magat, S. S. 1979. The use of leaf analysis in the conduct of coconut field fertilizer trials in the Philippines. The Philippines Journal of Coconut Studies , 4: 32-38.
- Michael, P. 1965. Hydrogen ion activity, Quoted in; Black, C. A. 1965. Methods of soil analysis, Amer. Soc. Agro. Inc., Madison, Wisconsin USA. 905-912.
- Nethsinghe, D. A. 1963. Maintaining fertility on coconut lands. Tropical Agriculturist 119, 1-12.
- Olsen, S. R. F. S. Watanabe, and I. A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bi-carbonate In: Circular No.939
- Prudente, R. L. and A. M. R. Mendoza. 1976. Response of inland coconut to inorganic fertilization from field planting. Philipp J Coconut Studies 1: 27-36
- Salgado, M. L. M. 1957. Report of the Soil Chemist. Annual Report of the Coconut research Institute for 1955, pp.17-29. Government Publications Bureau, Colombo
- Smith, R. W. 1969. Fertilizer response by coconut (*Cocos nucifera*) on two contrasting Jamaica Soils. Exp. Agr. 5: 133-145.
- Somasiri, L.L.W., N. Nadarajah., L. Amarasinghe, and H. A. J. Gunathilake. 1994. Land suitability assessment of coconut growing areas in the coconut triangle. Occasional Publication series No.3, Coconut research Institute, Lunuwila , Sri Lanka.
- Szott, L. 1987. Improving the productivity of shifting cultivation in the amazon basin of Peru through the use of leguminous vegetation. PhD thesis, North Carolina State University, Raleigh. 168pp.
- Thomas, K. M. and S. S. Nandra. 1973. Nutrient composition of coconut leaves and its relationship to nut yield in Tanzania, E Afr. Agr. Forestry Journal, 38: 170-175
- Troug. 1948. Lime in relation to availability of plant nutrients. Soil Sci. 65: 1-7
- Varghese, A. and Ama. 1991. Phosphorus dissolution pattern of different rock phosphates and its influence on biomass production and nodulation of *Pueraria phaseoloides*. Indian J Natural Rubber Research 4(2):118-122.
- Vincent, J. M. 1965. Soil Nitrogen. Agronomy, No. 10. Am. Soc. Agron. Pubn.
- Wijebandara, D. M. D. I. and L. L. W. Somasiri. 1994. Comparison of routine laboratory methods for the estimation of plant available phosphorus in soils of the Low Country Intermediate Zone of Sri Lanka. Tropical Agricultural Research, 6:211-222.
-