

**Comparison of soil phosphorous extraction by Olsen and double acid methods in acid soils of  
Western Kenya**

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**Abstract**

Phosphorous is an essential nutrient in plants required for root establishment. In the soil, it is applied as DAP, TSP or phosphate rocks. In acid soils, aluminium and iron are dominant and tend to “fix” phosphorous, making it unavailable for plant uptake. Phosphorous deficiencies are monitored through soil chemical analysis. There are many methods for the extraction of available forms; however the choice is dependent on several factors among them soil pH. Forty soil samples were collected from three different acid soils in Western Kenya. The samples were air dried, sieved under 2.0 mm sieve and stored in sample bags for subsequent analysis. Phosphorous extraction was carried out using a basic extractant (Olsen bicarbonate method) and acid extractant (double acid method). The extracts were measured colorimetrically by the ascorbic acid method at 880 nm wavelength. The methods were compared in terms of extracting efficiency, correlations and soil critical levels. The soils had a pH range of between 4.5 – 6.1; phosphorous, 1.66 – 55.37 mg P/ kg by Olsen method and 3.01 – 158.17 mg P /kg by double acid method. The methods were linearly correlated ( $r = 0.95$ ), however, double acid extracted more phosphorous than Olsen by a factor of 2.67.

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**Key words:** Olsen, phosphorous, double acid, acid soils, extractant.

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## Introduction

Phosphorus is essential for root growth and energy transfer processes in plants (Tisdale and Nelson, 1975). It occurs in the soil in both organic and inorganic forms, the latter being the most important for crop nutrition. Inorganic P occurs as various compounds of Ca, Fe and Al, in solution, surface films, solid state or exchangeable phosphate anions held by positive charges (Landon, 1991). Generally plants absorb P from the soil solution as primary orthophosphate ( $\text{H}_2\text{PO}_4^-$ ) and to a small extent as secondary orthophosphate ( $\text{H}_2\text{PO}_4^{2-}$ ) ions (Tisdale and Nelson, 1975). The readily available soil P is the solution P that is also referred to as P 'intensity' (Landon, 1991).

Soil testing provides information necessary for better understanding of the nature and properties of soils for their efficient use. The basic soil tests are physical, biological and chemical analysis. Of all the major plant nutrients, P possibly has the most complicated chemistry, at least as far as assessment of its soil levels and fertilizer application rates are concerned (Landon, 1991). Methods for determining soil P, its various forms and availability to plants have been essential in developing principles and knowledge, its nature and behavior in soils. Many methods exist and vary in principle and technical details. To select suitable method, clear details of the objective of P measurement, soil properties, equipment availability, extractant availability, accuracy and personnel availability is required. Most soil P determinations have two distinct phases. The first phase involves preparation of the solution and the second one quantitative determination of P in this solution measurement of intensity of the blue colour that is proportional to P in the extracts (Olsen and Sommers, 1982).

Use of sodium bicarbonate ( $\text{NaHCO}_3$ ) for soil P extraction was developed by Olsen *et al.* (1954). Phosphorus is extracted from the soil with 0.5M  $\text{NaHCO}_3$  at nearly a constant pH of 8.5. The  $\text{OH}^-$  and  $\text{CO}_3^{2-}$  in  $\text{NaHCO}_3$  solution, decrease the concentration or activity of  $\text{Ca}^{2+}$  and  $\text{Al}^{3+}$ , result in increased P solubility in soils. Double acid (0.05M HCl and 0.0125M  $\text{H}_2\text{SO}_4$ ) extraction was developed by Nelson *et al.* (1953) also known as Mehlich -1 test in North Carolina (in soils that fix P). The mixed acids are more effective than

HCl alone as a P extractant, and the results correlate better with plant response in soil with pH less than 6.0. Holford (1980) found that it extracts large amounts of non-labile P in soils with pH greater than 6.0. It is unreliable for calcareous or alkaline soils with high cation exchange capacity (CEC) or high base saturation (Thomas and Peaslee, 1973) and soils that have recently received rock phosphate (Yost *et al.*, 1982).

In this research, two extraction methods; the Olsen P and double acid method that indicate soil available P are investigated to assess their P extraction efficiency in three acid soils and also to determine if there is any correlation between these methods.

## Materials and Methods

### *Soil classification*

Soil units were selected and representative transects, traversing physiographic units and geologic units carried out. Along these transects routine soil auguring and profile descriptions were made at varying intervals. Particular attention was paid to the interpreted boundaries as they demarcate the soil types. After studies of soil profiles, the soil types were named according to their characteristics.

### *Soil sampling and pre – treatment*

Three sites were identified with acid soils in Western Kenya based on classification. These were; Humic Nitisols (Webuye East); Orthic Ferralsols (Teso) and Orthic Acrisols (Sega). In two Districts, 13 soil samples were collected and in one district 14 samples were collected in replicate. Surface soil was obtained at 0 - 20 cm depth by the "zigzag method" to ensure homogeneity. These were thoroughly mixed and a composite sample was obtained. The samples were then air – dried, ground, sieved under 2.0 mm sieve and stored in sample bags for subsequent analysis as per procedures outlined in Okalebo *et al.* (2002).

### *Soil pH determination*

25 grams of air- dried sample was transferred into a 100 ml plastic beaker and 50 ml of distilled water was added. The mixture was

shaken for 10 minutes on a reciprocal shaker and left to stand for 30 minutes. The mixture was stirred again for 2 minutes and the pH of the suspension was read using a pH meter.

**Olsen Bicarbonate Extraction**

2.5 grams of air dried soil was transferred into a 250 ml shaking bottle and 50 ml of Olsen’s extracting solution (0.5M NaHCO<sub>3</sub>, pH 8.5) was added to each bottle to achieve a 1:20 soil to extractant ratio. The extraction was achieved by shaking the mixture on an electrical shaker for 30 minutes. The suspension was then filtered through Whatman no. 42 filter paper. Phosphorous concentration in the filtrate was determined colorimetrically by the ascorbic acid method at 880 nm using a UV –VIS Spectrophotometer (Jenway).

**Double Acid extraction method**

A 2.5 g of air –dried soil sample was weighed into a 100 ml shaking bottle and 20 ml of the extracting solution (a mixture of 0.05 M HCl and 0.0125 M H<sub>2</sub>SO<sub>4</sub>) added. The mixture was shaken for 5 minutes and filtered through a Whatman no. 42 filter paper. A 5 ml of the extract was transferred to a 25 ml flask and diluted to the mark. Phosphorous concentration in the filtrate was determined colorimetrically by

the ascorbic method at 880 nm using a UV –VIS Spectrophotometer.

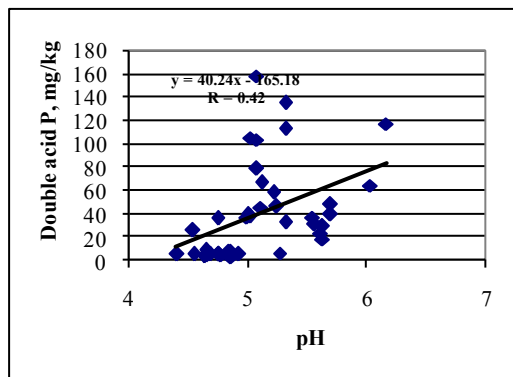
**Results**

**Soil classification**

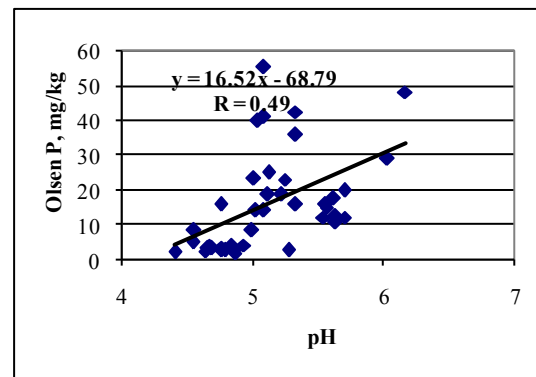
The soils of Webuye East are developed from tertiary or older basic igneous rocks. The soils are well drained, very deep, dark reddish brown, friable clay with humic topsoil. They were classified as humic Nitisols. Teso soils were developed on basic igneous rocks and basalt. They are well drained, very deep, red to dark red, friable to firm clay. The soils were classified as orthic Ferralsols. Segu soils were developed from basic igneous rocks or basalt, well drained, moderately deep to very deep, reddish brown and friable. They were classified as orthic Acrisol.

**Correlations of pH and soil P; Olsen and double acid phosphorous**

The correlation between soil pH and double acid P is shown in figure 1. There was no correlation between soil pH and double acid P (r = 0.42), implying that one cannot predict soil P using pH data alone. Figure 2 shows that there was also no correlation between soil pH and Olsen P (r=0.49), hence Olsen P cannot be estimated using soil pH values.

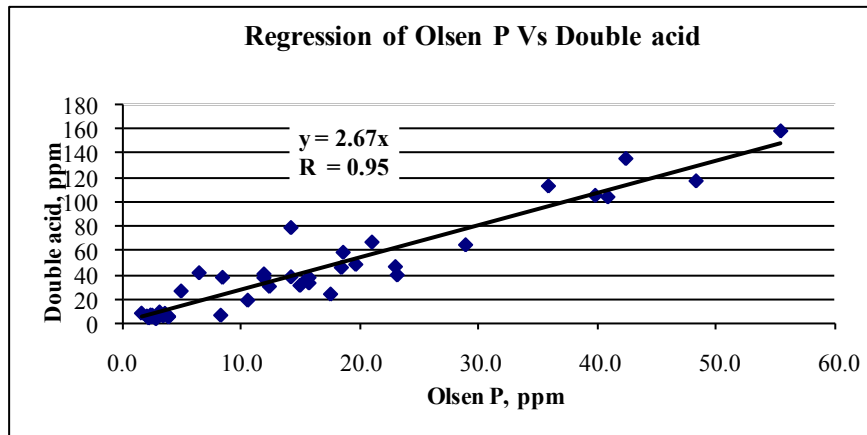


**Figure 1: Correlation between soil pH and Double acid P**



**Figure 2: Correlation between soil pH and Olsen P**

Figure 3 shows that there was a significant positive correlation (r= 0.95) between Olsen P and double acid P. This indicates that one can predict double acid P using soil Olsen P. For every 1 mg P/kg soil extracted by Olsen method, Double acid extracted 2.67mg P/kg soil.



**Figure 3: Correlation of Olsen P and Double acid extractants**

**Discussion and Conclusion**

The Olsen test, extracted less P as compared to the Double acid extraction. The NaHCO<sub>3</sub> test (Olsen *et al.*, 1954) generally extracts less P compared to Mehlich- 1 or Bray -1 test (Shuman *et al.*, 1988) except in highly buffered soils (Holford, 1980). To interpret NaHCO<sub>3</sub> soil tests values among diverse soils, the soil P sorption capacities should be considered except in buffered alkaline soils (Holford, 1980). Thomas and Peaslee (1973) found that for NaHCO<sub>3</sub> test, levels of 10mg/kg soil are adequate for optimum plant growth.

The Olsen extractant is useful for both acid and calcareous soils. In calcareous soils, increased P solubility is as a result of decreased Ca concentration by high CO<sub>3</sub><sup>2-</sup> to form CaCO<sub>3</sub>. In acid or neutral soils, the solubility of the Al and Fe phosphates increases as OH<sup>-</sup> concentration decreases. Higher OH<sup>-</sup> concentration leads to the formation of Al<sup>3+</sup> complex and Iron (III) oxide precipitate (Kuo, 1996). The increased negative charges and or decreased number of sorption sites for Al and Fe oxide surfaces at high pH could be possibly responsible for the desorption of sorbed P.

Double acid method extracted higher P than Olsen extractant by a factor of 2.67. The optimum soil P for Olsen method is normally set to be 10 mg /kg indicating that the optimum double acid extractable P will be

26.7 mg/ kg. Kamprath and Watson (1980) indicated that for Mehlich -1 test, P levels of 20-25mg/kg soil are adequate for plant growth in sandy soils, but 10ppm is required for fine textured soils. This method correlates well with Bray-1 test but not with Olsen - P test among diverse soils (Shuman *et al.*, 1988). For soils that have received rock phosphate the amount of P extracted is normally higher than Olsen and slightly lower than Bray-1 (Menon *et al.*, 1988). Mehlich -1 test has an advantage in that calcium (Ca) and magnesium (Mg) are as well extracted simultaneously (Nelson *et al.*, 1953)

In conclusion, phosphorous in acid soils can be extracted by either Olsen NaHCO<sub>3</sub> extractant or double acid extraction. However, double acid extracts higher amounts of P than Olsen method. In acidic soils, Olsen extractant first undergoes a neutralization reaction with the acid before carrying out the extraction. This explains the low extraction efficiency of the Olsen extractant.. For the soils studied, the optimum level of soil available P for double acid (26.7 mg/kg) is higher than that of Olsen P (10 mg/Kg). It is important to note that while reporting soil P data, the method of extraction should be indicated.

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