The pH of Leaf Water Extracts and Amount of Acid required lowering the pH of Leaf Water Extracts to 5.0

Mr. Njagi E. Silas
Chuka University College
Kenya

Prof. Jane I. Murungi
Department of Chemistry
Kenyatta University
Nairobi, Kenya.

Dr. R.N. Wanjau
Department of Chemistry
Kenyatta University
Nairobi, Kenya.

Abstract

Expansion of agricultural activities has led to farms being cultivation throughout the years which, has led to reduction in soil fertility. Use of commercial inorganic fertilizers in these farms tends to be ultimate solution in maintaining high yield. Too much use of inorganic fertilizers has led to low soil pH. Low soil pH reduces availability of essential nutrients to plants, results in formation of toxic chemicals in the soil and leads to low rate of decomposition of organic matter which is required to increase buffering capacity of the soil and also release nutrients. Soil acidity is reduced by liming which, is an expensive exercise and does not add fertility to the soil. There was need to look for alternative to liming materials which would at the same time be adding essential nutrients to the soil. This study was aimed at identifying potential plants whose leaves may be used to raise soil pH. The pH trends of leaf water extracts and the volume of 0.05M sulphuric acid required to reduce pH of the water extracts to 5.0 was determined. The pH of leaf water extract ranged from 3.85 to 8.08 for the 90 days it was monitored. The volume of acid required to reduce pH to 5.0 ranged from 0.1 to 20.7 ml. It was found that leaves of cassia, sunflower, Markhamia lutea, Croton macrostachyus, meru oak, Cordia africana, peacock flower and mexican sunflower produces extracts of high pH and these extracts accommodate large amount of acid before their pH goes below 5.0. These plants should therefore be planted in farms so that their leaves will spread in farms, be used to make manure or make leaf water extracts to be applied in farms.

Key words: Leaf water extracts, soil acidity, soil pH, liming materials

1. Introduction

Several decades ago, Kenyan farmers practiced shifting cultivation. This ensured that land was cultivated when fertile and so there was no need of applying fertilizers. As population increased, larger and larger pieces of land were cultivated to feed the growing population leaving no land fallow because there was no alternative land to cultivate. This made the land to be cultivated throughout thus reducing its fertility. To ensure that the land yield remains high, the nutrients required for crops to do well are added continuously and mainly in form readily available to plants. Addition of organic manure does not make the land to regain fertility fast enough and so to increase the yield, inorganic fertilizers are applied to crops in the form that can be absorbed immediately if water is present. The fast response of crops to inorganic fertilizers makes farmers use them more and continually in their farms. The commonly used and available inorganic fertilizers are for supplying the major macronutrient to plants. These fertilizers tend to lower the soil pH if applied for a long period of time since they are acidic. Studies have shown that areas with high organic content are not affected by acid deposition and it is believed that decayed products of these areas buffer the effects of acid (Murungi, 1990).

The more acidic the soil is, the more mobile will be elements such as iron, manganese, zinc, copper and other minor elements. Very low pH value can induce minor elements deficiency and cations such as K^+, Ca^{2+} and Mg^{2+} may leach (Paton, 1978). Most mineral compounds of nitrogen and sulphur are available at pH between pH of 6.0 and 8.0. A pH between 6.5 and 7.5 is usually the best for phosphorus availability. Metallic cations such as iron, manganese, copper and zinc form metallic compounds that decrease in solubility at high pH, so liming acidic soils can induce these cations deficiency. Molybdenum, which legumes require in high amount, is less available in acidic soils. Generally for most crops soil pH values of 5.5 to 7.5 is suitable for availability of most nutrients (Muchukuri *et. al.*, 2004).

Toxicity in soils results from aluminum and manganese species in soils. When pH of soil drops below 5.5, toxicity results due to presence of aluminium species. Mild effect of aluminum toxicity are lack of vigour in root growth and branching. It may also displace calcium and magnesium ions from colloids and interfere with access by plants to magnesium even with present. The other effects of elevated aluminum toxicity in soil is greater fixation of inorganic phosphate in form unavailable to plants (Stevenson, 1994). The reduction of aluminium toxicity by farmyard manure (organic matter) is considered to occur through aluminum precipitation, chelation on organic colloids or by complexation of soluble aluminum by organic molecules, especially organic acids (Hue & Ammien, 1989). Toxicity by manganese species result from the destruction of organic complexes on which it is fixed. It has general effects of heavy metals on protein when present at high concentration but can also inhibit some enzymes at concentration around 10^{-6} M (Kennedy, 1992; Townshed, 1995). Toxicity due to manganese can be corrected by enriching the soil with organic matter which increases the organic fixation of manganese and limits the lowering of the pH by a buffer action (Aubert & Pinta, 1977).

Decomposition of materials produced by plants in soil is done by bacteria, protozoa and fungi. At a pH of 4.0, fungi predominate while at pH of 7.0, bacteria are the predominant species. Studies here shown that the breakdown of leaf litter depends not only on pH but also the type of plant (Lampkin, 1990). In low soil pH situation, biological activity is reduced; slowing the turnover of organic matter and so reduces the release of nutrients.

Earthworms cannot tolerate acidic soils with pH below 5.0 and so under such conditions, minerals and organic matter are not blended together. Nitrification and nitrogen fixation takes place vigorously in mineral soils only at pH values above 5.5 (Hansen & Henriksen, 1989). Generally a soil in intermediate pH range (6-7) perhaps present in most satisfactory biological regime (Harry & Nyle, 1969).

Soils behave like a buffer and will buffer pH accordingly. Soils organic matter plays a major role in the buffering of both protons and metal cations concentration in the soil solution (Garrison, 1989). Soils containing large amount of clay and organic matter are highly buffered. In acidic soils the absorbed Al^{3+} will maintain equilibrium with Al^{3+} in the soil solution, which hydrolyzes to produce H^+.

$$\text{Clay}\left.\begin{matrix} Al^{3+} \\ Ca^{2+} \\ Mg^{2+} \\ K^{+} \end{matrix}\right\} \rightleftharpoons Al^{3+} + H_2O \rightleftharpoons AlOH^{2+} + H^+$$

If the H^+ is neutralized by adding base and the Al^{3+} in solution precipitate as $Al(OH)_3$, more exchangeable Al^{3+} will desorb to resupply the solution with Al^{3+} thus the pH remains the same or is buffered. The reverse of the above happens as acid is continually added to a neutral soil, OH^- in the solution is neutralized (Tisdale *et. al.*, 1993).

To raise soil pH calcium compounds such as calcium chloride, calcium hydroxide, calcium magnesium carbonate and slag are added to soil. Gypsum ($CaSO_4.2H_2O$) is also applied in acidic soils to enhance plant growth by releasing calcium and sulphate ions. The overall reaction for neutralization of aluminum derived soil acidity can be written as:

$$\text{Clay}\left.\begin{matrix}Al^{3+}\\ Ca^{2+}\\ Mg^{2+}\\ K^{+}\\ Al^{3+}\end{matrix}\right. + 3CaCO_3 + 3H_2O \longrightarrow \text{Clay}\left.\begin{matrix}K^{+}\\ Ca^{2+}\\ Mg^{2+}\\ Ca^{2+}\\ Ca^{2+}\\ Ca^{2+}\end{matrix}\right. + 2Al(OH)_3 + 3CO_2$$

The reduction of aluminium solubility can have a major positive impact on the fertility of acidic soils (Paton, 1978). To maintain high pH, continued liming is necessary. Increasing calcium concentration without subsequent increase in concentration of magnesium could result in negative magnesium balance and could have serious biological consequences since calcium and magnesium are believed to compete for same absorption routes in plant roots and intestinal mucosa of animals (Murungi, 1990).

The problem associated with increased use of inorganic fertilizers requires encouragement of use of organic fertilizers from plants especially for the poor farmers who cannot afford liming soils. Therefore there is need to find plant leaves whose aqueous extract have high pH and can accommodate high amount of acid before pH drops to 5.0.

2. Problem statement and justification

Continued application of inorganic fertilizers has increased soil acidity which has led to increased toxicity in the soil, low rate of decomposition of organic matter, reduced activity of soil organism and reduced buffering capacity of the soil. If plants with leaves that produce extracts that are not acidic and can accommodate much acid are identified, they can be planted by farmers in their farms. Leaves from these plants would be spread in farms or be used to make organic manure. This would reduce soil acidity at the same time adding organic matter in the soil which would improve farm output.

3. Objective

The objective of this study was to determine which local plants have leaves that produce extracts that may be used to reduce soil acidity.

4. Materials and methods

Samples were collected from Maara and Meru South districts of Eastern province in Kenya. Plant species that were common in farms were identified then random sampling was done to identify six plants of each species from which samples would be collected. Samples were collected from the identified plants in the month of August and September. Yellowing leaves and those that had just fallen were picked and then sun dried. The leaves of the same species (from six different plants) were mixed thoroughly, put into plastic bags and then transported to the laboratory. At the laboratory, the leaves were washed with distilled water and then sun dried for three days. The plant species sampled are given in Table 1.

Table 1: Species of plants sampled

Symbol	Scientific name	English name	Local name (Chuka name)
E1	*Pinus patula* Schleditendal & Chamisso	Mexican weeping pine	-
E2	*Casuarina equisetifolia* L	Sea pine/whistling pine	-
E3	*Cassia spectabilis* DC	Cassia	Mubangua mweru
E4	*Grevelia robusta* A. Cum	Silky oak	Mukima
E5	*Cupressus lusitanica* Mill	Mexican cypress	Mutarakwe
E6	*Eucalyptus saligna* Sm	Sydney blue gum	Mubau maguta
E7	*Jacaranda mimosifolia* D.Don	Jacaranda	Mucakaranda
F1	*Macadamia tetraphylla* L.A.S. Johnson	Macadamia nut	Mukandania
F2	*Magnifera indica* L	Mango	Mwembe
F3	*Persea americana* Miller	Avocado	Mukondobia
F4	*Manihot esculenta* Crankz	Cassava	Mwanga
F5	*Musa sapientum* L	Banana	Irigu
F6	*Cajanas cajan* (L) Mill sp	Pigeon pea	Ncugu
F7	*Carica papaya* L	Paw paw	Mubabai
F8	*Helianthus annus* L	Sunflower	Mbembe cia nguku
F9	*Pennisetum purpuream* Schumach	Napier grass	Muthara
L1	*Newtonia buchananii*(Bak)Gilb& Bont	-	Mukui
L2	*Bridelia micrantha* (Hochst) Baill	-	Mukwego
L3	*Markhamia lutea* (Benth) K. Schum	-	Muu
L4	*Cardia africana* Lam	-	Muringa
L5	*Croton macrostachyus* Del	-	Mutuntu
L6	*Vitex keniensis*	Meru oak	Muburu
L7	*Sapium ellipticum* (Krauss) pax	-	Muthatha
L8	*Albizia gumifera*(JFGmel)C.A Sm	Peacock flower	Mukorwe
L9	*Tithonia diversifolia* (Hernst) A Gray	Mexican sunflower	Magana/araka
L10	*Lantana camara* L	Lantan (tick berry)	Mucimoro
L11	*Rauvolfia caffra* Sond	-	Muthuba

[Key; E for exotic trees, F for fruit or fodder, L for local indigenous trees and dash (-) where name was not available]

Portions of 100g of leaves of each species were weighed and soaked in 5 litres of distilled water in plastic containers. The pH of this water (where leaves were soaked) was determined everyday using a pH meter. On 30th, 60th and 90th day, 100 ml of leaf water extract was filtered from the plastic containers and titrated to pH of 5.0 using 0.05 M sulphuric acid. This was repeated using 100ml of distilled water kept at the same condition as that soaked leaves to remove the effect of dissolved carbon dioxide. The volume of water was readjusted to 5 litres using distilled water.'

5. Results and discussions

This section presents the research findings in line with the objective that guided the study

a) The pH of leaf water extracts

The pH of leaf water extract used when soaking leaves was 6.65. The pH values of leaf water extract on day 1, 5, 30, 60 and 90 are given in Table 2

Table 2: The pH of the leaf water extract on day 1, 5, 30, 60 and 90 (n=3)

Species	1st day	5th day	30th day	60th day	90th day
E1	4.94±0.04	4.60±0.04	5.26±0.05	6.28±0.07	6.64±0.05
E2	5.40±0.07	5.41±0.08	7.10±0.04	7.57±0.05	7.80±0.04
E3	5.67±0.05	5.06±0.06	5.17±0.07	6.01±0.05	6.61±0.08
E4	5.51±0.07	5.08±0.08	5.22±0.05	5.68±0.02	5.84±0.03
E5	5.24±0.06	4.87±0.04	5.47±0.07	5.71±0.02	5.77±0.05
E6	4.98±0.04	4.20±0.04	4.00±0.04	5.17±0.07	4.69±0.04
E7	4.95±0.04	4.46±0.04	4.78±0.04	5.32±0.06	4.95±0.04
F1	5.28±0.07	5.01±0.05	5.41±0.02	5.74±0.03	6.63±0.05
F2	5.20±0.06	4.36±0.04	4.58±0.04	4.97±0.02	4.53±0.05
F3	5.48±0.05	5.01±0.06	4.54±0.04	5.09±0.08	5.03±0.07
F4	5.47±0.07	5.51±0.03	4.87±0.04	5.14±0.02	6.05±0.05
F5	5.69±0.08	5.30±0.05	6.64±0.04	7.32±0.06	7.47±0.04
F6	5.33±0.04	5.00±0.06	5.70±0.07	5.70±0.02	5.87±0.02
F7	5.55±0.07	5.25±0.03	5.62±0.02	5.25±0.08	5.72±0.04
F8	6.64±0.06	6.03±0.07	5.69±0.02	6.35±0.04	7.09±0.02
F9	5.44±0.05	5.23±0.02	5.37±0.07	5.12±0.03	5.58±0.05
L1	4.97±0.04	4.78±0.04	5.21±0.08	5.29±0.02	5.10±0.03
L2	5.20±0.03	4.78±0.04	5.17±0.06	5.38±0.02	5.63±0.03
L3	5.77±0.07	5.33±0.06	6.74±0.05	7.08±0.04	7.49±0.04
L4	5.98±0.05	6.14±0.08	7.23±0.04	7.42±0.04	7.69±0.04
L5	5.69±0.06	5.42±0.02	6.19±0.07	5.75±0.02	6.13±0.03
L6	6.11±0.07	5.58±0.03	5.38±0.08	6.37±0.06	6.01±0.05
L7	4.81±0.04	4.43±0.04	4.11±0.02	4.23±0.04	3.72±0.04
L8	6.25±0.05	6.35±0.03	7.14±0.04	7.65±0.04	8.08±0.04
L9	6.35±0.05	6.12±0.08	6.50±0.07	6.51±0.02	6.99±0.06
L10	5.92±0.06	5.49±0.07	5.07±0.05	5.83±0.05	5.24±0.02
L11	5.98±0.08	5.40±0.04	5.02±0.03	5.26±0.06	4.84±0.04

The pH of leaf water extract for all species dropped from the initial 6.65 to below 5.50 except for sunflower, meru oak, peacock flower, *Cordia africana* and Mexican sunflower by the fifth day. Within the 90 day period, the pH rose above 7 for whistling pine, sunflower, *Markhamia lutea*, *Cordia africana* and peacock flower. The pH did not rise above 5.5 after the initial fall for sydney blue gum, mango, *Newtonia buchanii*, *Sapium ellipticum* and *Rauvolfia caffra*. However some species such as jacaranda, avocado and napier grass had pH rising 5.5 and other times below. There were species whose pH took less than 30 days to rise above 5.5. These are whistling pine , banana, pigeon pea, macadamia and *croton macrostachyus.* Those species whose pH did not drop below 5.5 throughout the 90 days period, rose above 7.0 or took less than 30 days for pH to rise above 5.5 may be appropriate to plant in soil affected by acidity so that their leaves may be spread on soil or be used to make manure for use in such farm. These species Mexican weeping pine, whistling pine, banana, pigeon pea, sunflower, *Markhamia lutea*, *Cordia africana*, *Croton macrostachyus*, meru oak, peacock flower and Mexican sunflower. However species like sydney blue gum, jacaranda, mango, *Sapium elliptium* and *Rouvoifia caffra* produced extract with pH below 5.0 by 90th day and would therefore not be appropriate for use in acidic soil because of their acidity, so these trees should be reduced in farm.

b) Volume of acidic required to adjust pH of leaf water extracts to 5.0

The volume required to adjust pH of 100 ml of leaf water extracts to 5.0 on 30th, 60th and 90th is given in Table 3

Table 3: Volume (ml) of 0.05 M of sulphuric acid required to adjust pH of 100 ml of leaf water extract to 5.0 (n=3)

Sample	30th day	60th day	90th day
E1	1.0±0.11	3.0±0.14	3.6. ±0.21
E2	7.9±0.21	9.2±0.32	9.5±0.14
E3	0.6±0.12	11.8±0.21	14. 8.±0.25
E4	2.6±0.16	2.5±0.14	2.6±0.24
E5	1.7±0.11	2.1±0.16	2.2±0.12
E6	-	0.1±0.12	-
E7	-	0.2±0.12	-
F1	0.6±0.12	1.6±0.14	1.8±0.11
F2	-	-	-
F3	-	0.4±0.11	0.5±0.11
F4	-	5.6±0.14	9.3±0.25
F5	5.1±0.21	8.7±0.24	8.9±0.32
F6	2.4±0.12	3.4±0.16	5.1±0.14
F7	7.8±0.21	8.7±0.17	9.4±0.32
F8	9.6±0.14	20.6±0.25	20.7±0.32
F9	3.5±0.16	3.9±0.16	4.2±0.17
L1	1.5±0.12	1.4±0.16	0.3±0.11
L2	2.6±0.16	2.0±0.11	1.4±0.16
L3	9.1±0.14	14.5±0.21	16.8±0.17
L4	9.2±0.24	12.9±0.14	17.1±0.32
L5	9.7±0.17	14.7±0.21	17.2±0.32
L6	5.0±0.24	12.4±0.14	14.1±0.25
L7	-	-	-
L8	7.6±0.14	12.0±0.25	14.1±0.36
L9	10.9±0.21	11.8±0.17	15.8±0.24
L10	1.3±0.11	1.8±0.11	2.0±0.12
L11	-	0.1±0.11	-

[Dashes (-) are indicated where titration was not done because the pH of leaf extract was below5.0]

From Table 3, mango (F2) and *Sapium ellipticum* (L2) had there pH below 5.0 so their volume were not determined. Sydney blue gum (E6), jacaranda (E7) and *Raufolfia caffra* (L11) had pH below 5.0 on 30th and 90th (so their volume were not determined on these days) but on 60th day, they had pH of slightly above 5.0 and their volumes were found to be 0.2 ml and less. Generally, the volume of acid required to reduce pH to 5.0 increased with time except for silky oak (E4) which remained almost constant and for *Newtonia bachananii* (L1) which decreased with time. By 60th day , the volume required by extract of mexican cypress (E5), banana (F5) and sunflower (F8) had reached maximum or increased by at most 0.2ml by 90th day. The sunflower (F8) leaf extracts required the highest volume of acid of all the species studied (20.7ml by 90th day) and was the only one that needed more than 18ml. The pH of leaf water extracts did not affect the volume required to reduce pH to 5.0. for instant sunflower leaf extracts required highest volume by 90th day (20.7 ml) while peacock flower leaf extracts had the highest pH value of 8.08 by the same day (but had a volume of 14.1 ml). Therefore, volume required to adjust pH to 5.0 was found to depend on the species of plant and not the pH of the leaf extracts. This is due to the fact that leaf extracts of different species have different buffering capacities.

From the result cassia (E3), sunflower (F8), *Markhamia lutea* (L3), *Cordia africana* (L4), *Croton macrostachyus* (L5), meru oak (L6), peacock flower (L8) and Mexican sunflower (L9) may be planted in soil affected by acidity because they required volumes above 10 ml by 60th day and increased further by 90th day. The other species had volumes below 10 ml even by 90th day.

6. Conclusion

This study showed that when leaves are soaked in distilled water, the pH of water drops and then rises after some times. The pH of leaf water extracts depends on the type of plant and the length of soaking leaves. The volume of acid required to reduce pH to 5.0 was found to depend on type of plant and the length of soaking leaves. The plant species that have leaves whose extracts have high pH and required large quantity of acid for pH to drop below 5.0 are appropriate to plant in farms. These are cassia (E5), sunflower (F8), *Markhamia lutea* (L3), C*ordia africana* (L4), *Croton macrostachyus* (L5), meru oak (L6), peacock flower (L8) and mexican sunflower (L9). Leaf extracts of these plants may be applied in soils affected by acidity to act as liming materials.

7. Recommendations

It is recommended that farmers plant cassia, sunflower, *Markhamia lutea*, *Croton macrostachyus*, meru oak, *Cordia africana*, peacock flower and mexican sunflower in their farms and use their leaves to improve the soil. These plants should be planted with other crops in farms (agroforestry), live fences (e.g. mexican sunflower) or mixed cropping (e.g. sunflower and maize). Leaves of these plants should be spread in farms and be used to make manure that will be used in farms. These leaves can also be used to make leaves extracts that will be applied to crops in farms. This will raise soil pH as well as improving soil fertility which will lead to high farm produce.

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