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Studies on soil fertility status of coffee growing regions in Wayanad district

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Abstract

Top soil in Wayanad region is prone to disturbance and erosion, as the coffee growers' practice scraping, scuffling and cover digging. It is necessary to conserve the inherent fertility of top soil by minimum disturbance during farming operations. Otherwise soil deterioration can become one of the major constraints for crop production in the present day exploitative cultivation of plantation crops. It is well known that nutrient availability is influenced by their distribution in the soil as well as other soil characteristics. Soil fertility is the key to meet the nutrient requirement of the crops. Soil test based nutrient management will increase the crop productivity there by helping to save the fertility. The study, carried out to understand the fertility status of the coffee soils, revealed a higher acidity (98%) with deficiencies of calcium (32%), magnesium (96%) and boron (31%) limiting the coffee productivity in the district. The coffee area in the district is strongly acidic (69%) due to lack of liming and continuous use of acid producing fertilizers. Fifty per cent of soil samples were high in phosphorus which in turn impair the nutrient balance and affects micronutrient absorption by plants. Deficiency of calcium and magnesium affects uptake of other nutrients which upsets cellular functions. In coffee, boron deficiency will reduce the productivity by affecting flowering and fruit set. Amelioration of soil acidity and optimal use of major, secondary and micronutrients are must to enhance coffee productivity in the district. Application of manures and fertilizers based on soil test values will save the fertilizers and also sustain the soil health. Integrated management of plant nutrients is essential to achieve sustainable coffee crop production.

Keywords: Coffee, major nutrient, micronutrient, secondary nutrient, soil fertility

Introduction

Wayanad district in Kerala is situated between 76°26'11" and 75°46'38" East and 11°26'28" and 11°48'22" North. The difference in altitudes of each locality within the district presents a variation of climatic conditions in different places. The altitude varies from 700 to 2100 m above mean sea level (MSL) and covers 2132 km^2. The mean average annual rainfall in the district is 2322 mm. The highest annual rainfall is received in Western parts of the district and it tapers towards eastern parts. Mean maximum and minimum temperatures are 29 °C and 18 °C, respectively.

Plantation crops constitute 38 per cent of the cropped area. Kerala occupies the second position in area and production of coffee after Karnataka (Anonymous, 2000-2016). Out of the total area, nearly 79 per cent of the area is found in Wayanad district alone with 85 per cent of the total coffee production in the State. Robusta coffee is ubiquitous in Wayanad and it is cultivated in every Panchayat, both in the form of large plantations and small

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holdings with lots of diversification. The economy of Wayanad depends mainly on coffee. Paddy based cropping system involving paddy, vegetables and banana is also prominent. Cardamom, black pepper, ginger, turmeric, banana, tubers and vegetables are the other crops cultivated.

From sixties to eighties, area under robusta coffee has increased by 101 per cent (Anonymous, 2000 - 2016). Due to the use of high yielding varieties and fertilizers, during the year 1970-71, coffee production increased to 111 per cent and again there was jump up to 211 per cent during the year 2000-01. Coffee productivity increased to 122 per cent during 2000-01; further it has remained more or less static.

In Wayanad, top soil is prone to disturbance and thereby erosion, as growers' practice scraping, scuffling and cover digging. Hence, it is necessary to conserve the inherent fertility of topsoil by minimum disturbance during farming operations; otherwise soil deterioration can become one of the major constraints in sustaining crop production in the present day exploitative cultivation in plantation crops. It is well known that nutrient availability is influenced by their distribution in the soil as well as other soil characteristics and yield. Soil fertility is the key to understand the nutrient requirement of the crops. Hence, the objective of this study was to characterize the fertility status of soils and recommend soil test based nutrient management which will increase sustained crop productivity, thereby helping to save the environment.

Materials and methods

The study envisaged assessment of surface soil fertility of coffee-growing areas in Wayanad district. As this study was restricted to assessment of surface soil fertility in Wayanad district, methods employed for sampling, laboratory analysis and organization of the data sets in electronic form are only presented in this paper. Depending on the extent of coffee cultivated in Wayanad district, number of samples to represent each taluk and village were estimated and a target of about 1341 soil samples was finalized for sample collection and each soil sample represented 50 ha. The soil samples were collected at the depth of 0-9 inches (0 to 22.5 cms) by using core sampler. A total of 1341 samples were collected from three taluks namely Vythri (539 soil samples), Mananthavady (357 soil samples) and Sulthan Bathery (445 soil samples), and analyzed for 10 soil fertility parameters: soil reaction (pH), organic carbon, major plant nutrients (phosphorus and potassium) (Walkley and Black, 1934; Bray and Kurtz, 1945; Watanabe and Olsen, 1965; Jackson, 1973) secondary nutrients (calcium, magnesium and sulphur) and micronutrients (copper, zinc and boron) (Lindsay and Norwell, 1978; Gupta, 1967). The data generated were used for assessing soil fertility and to give nutrient management recommendations.

Results and discussion

Soil Reaction

Analytical data on soil pH of the 1341 soil samples collected from the coffee estates of Wayanad district clearly indicated that about 98 per cent of soils were acidic in reaction. The soil pH varied from 4.1 to 7.5 and the corresponding lime requirement to correct the soil acidity ranged from 0.5 to 2.0 tons acre^{-1}. Soil acidity is a grave problem in Wayanad district and needs amelioration by liming. High acidity observed in the soils of Wayanad can be attributed to the leaching of calcium and magnesium due to high rainfall, rolling terrain, continuous application of acid forming fertilizers and the absence of liming practices for long periods. The frequency of soil reaction classes is presented in Figure 1.

Soils were categorized into eight major classes namely, (i) Ultra acid (pH <3.5), (ii) extremely acid (pH 3.5-4.5), (iii) very strongly acid (pH 4.6-5.0),

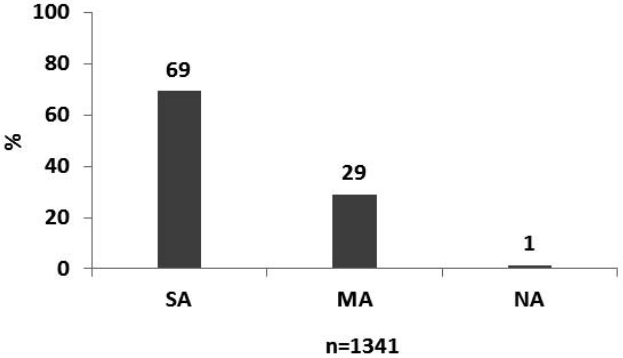

Fig. 1. Frequency of soil reaction classes: SA - Strongly acid, MA - Moderately acid and NA - Neutral and alkaline

(iv) strongly acid (pH 5.1-5.5), (v) moderately acid (pH 5.6-6.0), (vi) slightly acid (pH 6.1-6.5), (vii) neutral (pH 6.6-7.5), and (viii) slightly alkaline (pH 7.6-8.0).

Among the 1341 soil samples collected from the district, about 1 per cent of the soils were found to have extremely acid pH (3.5-4.5), 25 per cent very strongly acid pH (4.6-5.0), 43 per cent strongly acid pH (5.1-5.5), 23 per cent moderately acid pH (5.6-6.0), 6 per cent slightly acid pH (6.1-6.5) and 1 per cent neutral pH (6.6-7.5).

The soils representing all the three taluks of Wayanad district, namely, Vythri, Mananthavady and Sulthan Bathery were found to be almost equally acidic in reaction and their per cent distribution under different pH classes is depicted in Figure 2.

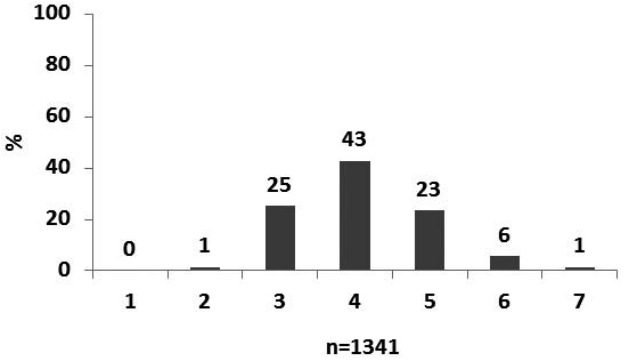

Fig. 2. Frequency of Wayanad district soil under different pH classes

Among three taluks of Wayanad district, 72 per cent of soil samples were strongly acidic in Sulthan Bathery followed by Mananthavady (71%) and Vythri taluks (66%). Moderately acidity of 33 per cent of samples was noticed in Vythri, 28 per cent in Mananthavady and 26 per cent in Sulthan Bathery taluks. Only negligible per cent (1-2) of soil samples were neutral in all the three taluks (Fig. 3).

Among the taluks, soils in Sulthan Bathery were very strongly acidic (30%) followed by Mananthavady (29%) and Vythri (19%) (Fig. 4). There was no much difference in between the taluks with respect to the slightly acidic and neutral classes.

Though coffee is reported to be grown in soils of pH varying from 4.0 to 8.0 in other countries, results of studies conducted in those countries indicated that neither of the extremes was suitable for achieving

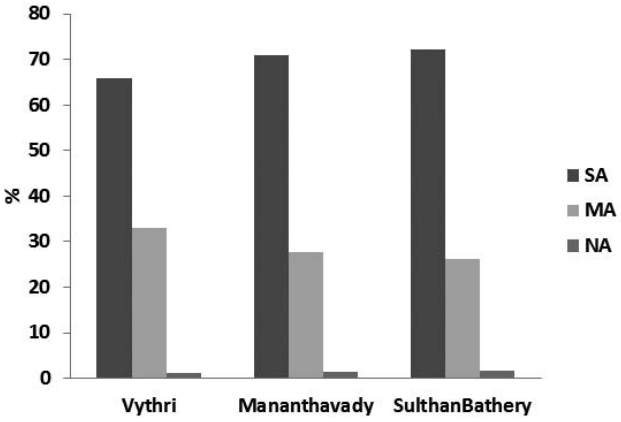

Fig. 3. Per cent distribution of soil reaction classes representing different taluks: SA-Strongly acid, MA-Moderately acid and NA-Neutral and alkaline

economic yields. In India, soil pH of 5.8 to 6.2 is established as ideal for coffee cultivation based on the studies conducted. So maintaining the soil pH at optimum is very crucial to realize the production potential of a variety. The growth and yield of coffee would not be normal in highly acidic soils due to toxicity of manganese, aluminium and deficiency of phosphorus.

The present study has confirmed the fact that liming is not regularly practiced by majority of the coffee growers of Wayanad district and hence there is a need to create awareness among the growers about the importance of liming in realizing better coffee yields.

Status of organic carbon

The organic carbon status of the soils cropped by coffee in Wayanad district was found to range from medium to high in majority of the samples.

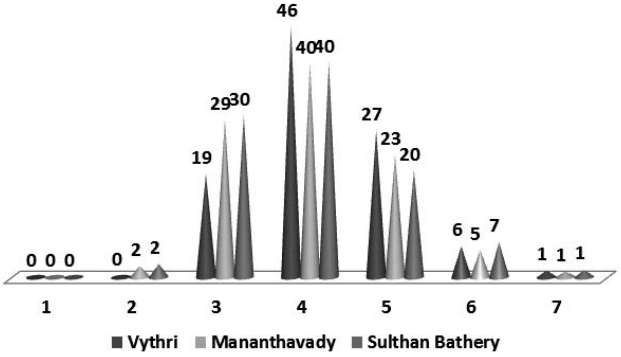

Fig. 4. Per cent distribution of soils of different taluks under different pH classes

The percentage of soil samples distributed into low (<1%), medium (1-2.5%) and high (>2.5%) classes of organic carbon is presented in Figure 5.

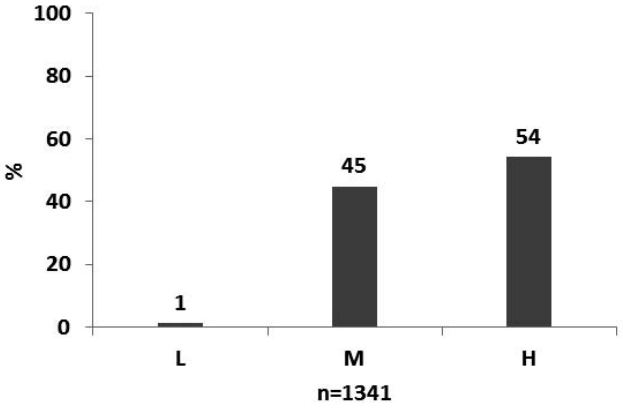

Fig. 5. Frequency of organic carbon classes: L-Low, M-Medium, H-High

Since coffee is grown under shade in India, addition of leaf litter from shade trees also contributes to the build-up of soil organic matter. Apart from this, a high percentage of coffee leaves added during harvesting of fruits, leaf abscission during both dry and rainy seasons and periodical pruning of coffee plants also add to the organic matter status of soil. Organic matter plays an important role in the productivity of coffee plants because of its influence on the physical, chemical and biological properties of soil. It provides aeration; favors water infiltration, reduces erosion and restrains the acidity induced by fertilizers. High acidity in the soil not only reduces microbial activity, but also leads to the development of toxicity due to the presence of aluminium and manganese in high concentrations. Hence, organic matter in soils should be managed by providing adequate addition and adopting good soil cultivation practices. In young plantations, adequate soil coverage should be provided to preserve soil organic matter and fertility.

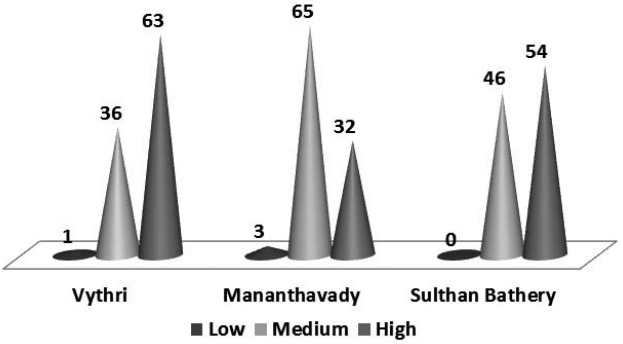

Fig. 6. Per cent distribution of soils of each taluks under different organic carbon classes

The organic carbon content of the soils representing the three taluks of the district ranged from medium to high in majority of the samples and the variation in the organic carbon status among the taluks was not very significant (Fig. 6).

Available phosphorus in soils

The soil available phosphorus (P) content of the soils of the district ranged from 1 to 749 kg ha^{-1} and was above 25 kg ha^{-1} in about 50 per cent of the soils. The frequency of available P classes has been categorized as low (<10 kg ha^{-1}), medium (10-25 kg ha^{-1}), high (> 25-100 kg ha^{-1}), very high (>100-200 kg ha^{-1}), extremely high (>200 kg ha^{-1}) and it is presented in Figure 7.

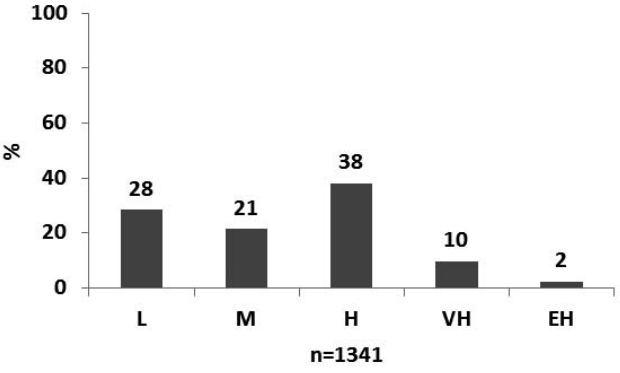

Fig. 7. Frequency of available phosphorus classes: L-Low, M-Medium, H-High, VH-Very high, EH-Extremely high

Among the taluks, Vythri was found to have higher (43%) number of P deficient soils compared to Mananthavady (20%) and Sulthan Bathery (12%). The per cent distribution of soils representing the taluks of the districts under different classes of available P is presented in Figure 8.

The data on available P over a period of 30 years showed a clear cut shift from low to high P category. About 60 per cent of the samples, that were low during 1980s reduced to 40 per cent during 1990s and further reduced to 22 per cent during 2016. On the other hand, the percentage of samples classified under high category gradually increased from 17 to 36 per cent over three decades (Shiva Prasad *et al.*, 2017).

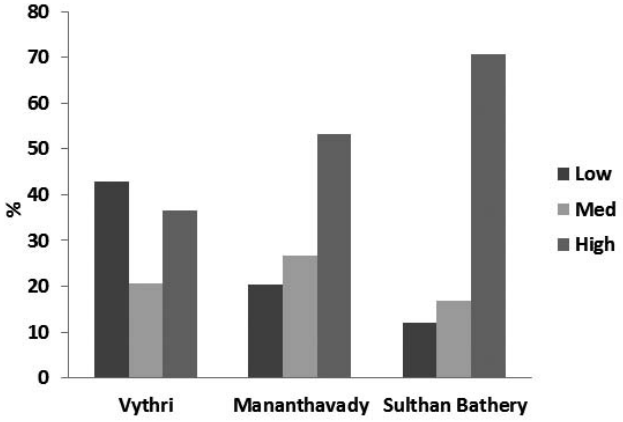

Fig. 8. Per cent distribution of soils of each taluks under different available phosphorus classes

Results of the present study also have indicated buildup of available P in the coffee growing soils of Wayanad district. Application of water insoluble phosphatic fertilizers like Mussorie rock phosphate was very common in coffee cultivation up to 1990s. Consequent to deregulation of fertilizer policy and non-availability of Mussorie rock phosphate, use of water soluble complex fertilizers came in to practice. This could be one of the reasons for buildup available phosphorus in coffee soils. Unlike N and K, P does not leach out of the soil and under high acidic condition gets fixed in the soil in to unavailable forms. Once the P fixing capacity of the soils is satisfied, accumulation of available phosphorus in soils can happen.

Reducing the dose of P fertilizer under high soil available P condition is necessary for ensuring balanced nutrient supply to the plants and this also economises the coffee cultivation. Phosphorus and Zn are known to have antagonistic interaction and so P inputs in excess can aggravate zinc deficiency (Raju *et al*., 1982). Soil amendments like lime can lead to release of P fixed by the soil constituents into the available pool. Hence, it is recommended to get the soil tested regularly and apply lime and fertilizers in required quantities only.

Available potassium in soils

Potassium (K) is of significant importance to the physiological development of coffee plants, particularly for the development and maturity of fruits. Like N, K also is subjected to leaching losses from the soil during heavy rains and application in split doses would help in improving the fertilizer use efficiency. The available K ranged from 48 to 1592 kg ha^{-1} in soils of Wayanad district and their per cent distribution under available potassium classes is presented in Figure 9. The available K status was low (<125 kg ha^{-1}) in 19 per cent of the soil samples. A major part (47%) of the soils of Wayanad district belonged to the medium (125-250 kg ha^{-1}) K status. About 33 percent of soil samples were high (>250 kg ha^{-1}) in K content.

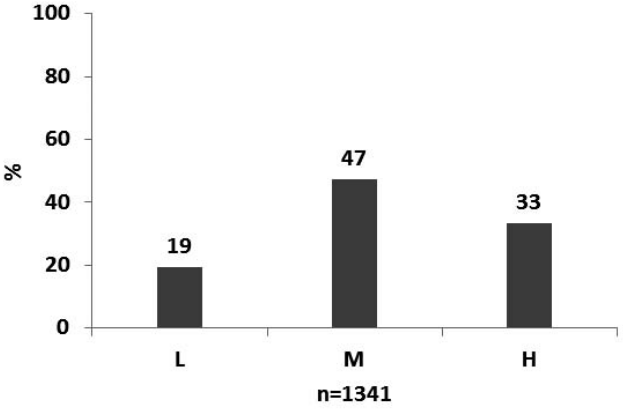

Fig. 9. Frequency of available potassium Classes: L-Low, M-Medium, H-High

In soils representing the three taluks of the district, percentage of K deficient soils ranged from 17 to 25 (Fig. 10) and the K deficient soils were comparatively more in Sulthan Bathery (25%). Maintenance of high levels of organic matter, abating soil acidity through liming, application of K fertilizers in doses recommended based on soil test data and crop requirement

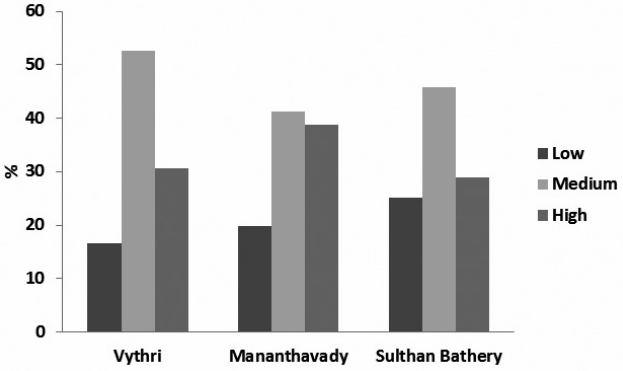

Fig. 10. Per cent distribution of available potassium in each taluks

would be helpful in managing K nutrition to coffee plants effectively.

Available calcium in soils

Calcium (Ca) is important for the development of terminal buds and flowers. Calcium, being immobile in the plant, deficiency appears in young leaves which are often distorted, small and abnormally green. Other symptoms include desiccation of terminal buds.

The available Ca status of soils in the district varied from 57 to 4694 mg kg^{-1} and about 32 per cent of the samples analyzed were found to be deficient in available Ca content. The classification of the soils into deficient (<600 mg kg^{-1}) and sufficient (>600 mg kg^{-1}) categories is presented in Figure 11. The distribution of Ca deficient soils in the three taluks varied from 25 to 36 per cent (Fig. 12). More deficiency of Ca was noticed in Vythri (36%), followed by Mananthavady (34%) and Sulthan Bathery (25%). Getting the soil samples tested periodically and liming will help in correcting soil pH as well as improving the Ca status of the soils.

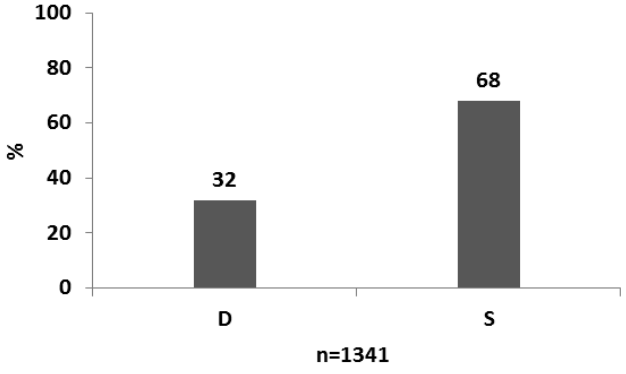

Fig. 11. Frequency of available calcium classes: D-Deficient, S-Sufficient

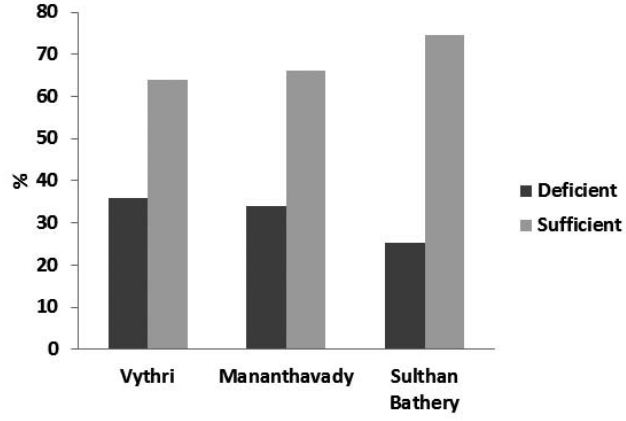

Fig. 12. Per cent distribution of soils of each taluks under different available calcium classes

Available magnesium in soils

Magnesium (Mg), an essential secondary nutrient, is an important constituent of chlorophyll and hence indispensable for photosynthesis. The element is mobile within the plant and the deficiency first appears on older leaves. The typical symptom of Mg deficiency is expressed as interveinal chlorosis of the leaves and severe deficiency leads to drying of leaf tips. Magnesium deficiency shortens the leaf life and is therefore detrimental to yield.

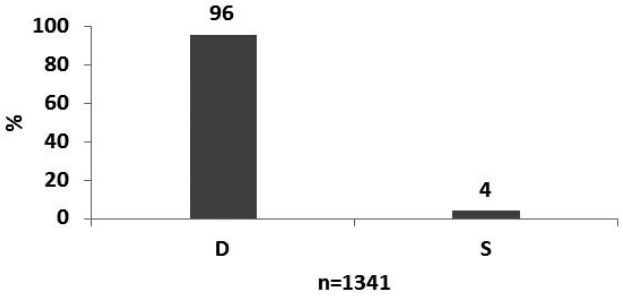

Fig. 13. Frequency of available magnesium classes: D-Deficient, S-Sufficient

The available Mg status of soils cropped to coffee in Wayanad district ranged from 0.1 to 450.9 mg kg^{-1} and found to be deficient in about 96 per cent of the samples. The classification of the soils into deficient (<180 mg kg^{-1}) and sufficient (>180 mg kg^{-1}) categories is presented in Figure 13. Distribution of Mg deficient soils in the three taluks of the state ranged from 95 to 97 per cent (Fig. 14). To improve the Mg status of these soils application of dolomitic lime stone containing calcium Mg carbonate is suggested. The practice of applying dolomitic lime stone to correct soil acidity is hardly seen among the growers of the district. Foliar spray of magnesium sulphate (0.5 per cent) also can be recommended for quick replenishment of the nutrient to plants in deficient soils.

Available sulphur in soils

Sulphur (S) is an essential constituent of amino acids and has role in photosynthesis as well as the

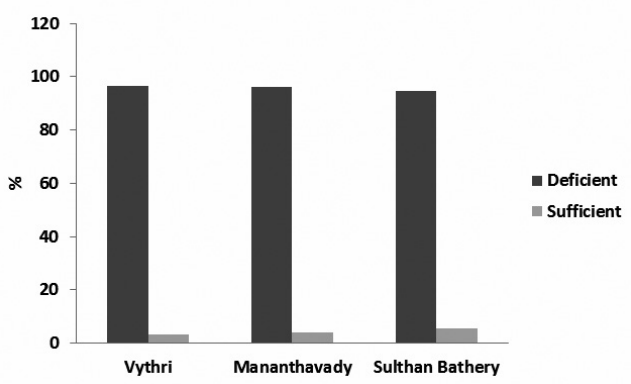

Fig. 14. Per cent distribution of soils of each taluks under different available magnesium classes

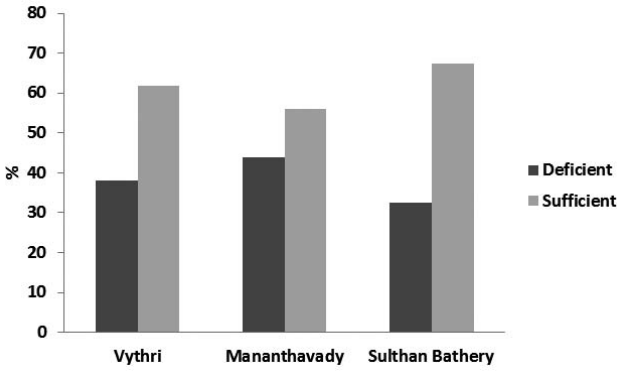

Fig. 16. Distribution of soils of taluks under different available sulphur classes

quality of coffee. Sulphur deficiency symptoms, *viz.*, discolouration and chlorosis appear first in younger leaves. Like N and K, S also is likely to be lost from the soil through leaching.

The available S content ranged from 1.6 to 72.5 mg kg^{-1} in soils of Wayanad district. About 39 per cent of the soils were found to record low available S content when classified into sufficient (>10 mg kg^{-1}) and deficient (<10 mg kg^{-1}) categories (Fig 15). Distribution of S deficient soils in the three taluks of the state ranged from 33 to 44 per cent (Fig. 16). Sulphur deficiency can be corrected by applying S containing fertilizers to soil or through foliar spray of magnesium sulphate.

Available zinc in soils

Zinc (Zn) is a constituent of many enzymes and influences translocation and transport of phosphorus in plants. Deficiency symptoms include interveinal chlorosis, first appearing on younger leaves and reduction in the size of young leaves, which are often clustered at the top, normally known as "rosette" appearance of leaves.

The available Zn status of the soil samples belonging to Wayanad district is fairly good and it ranged from 0.1 to 150.9 mg kg^{-1}. Classification of soils in to sufficient (>1 mg kg^{-1}) and deficient (<1 mg kg^{-1}) classes indicated the deficiency of zinc in about 15 per cent of the samples (Fig. 17). Distribution of Zn deficient soils in the three taluks of the state ranged from 11 to 21 per cent (Fig. 18). Foliar application of properly neutralized zinc sulphate solution (0.25%) can be recommended to supply zinc to the plants in deficient soils.

Available copper in soils

Majority of the soils of Wayanad district cultivated to coffee were found to be well supplied with the micronutrient copper (Cu) and the availability ranged from 0.3 to 381.0 mg kg^{-1}.

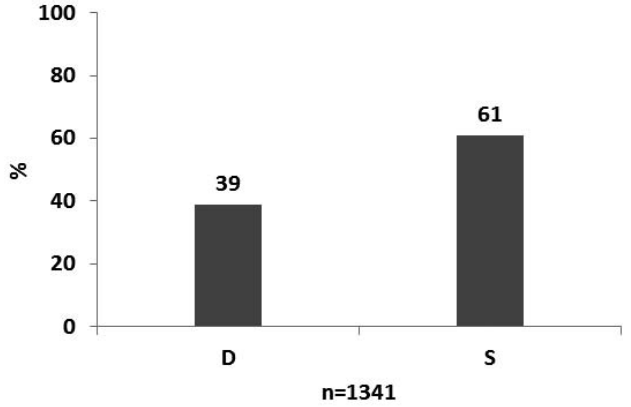

Fig. 15. Frequency of available sulphur classes: D-Deficient, S-Sufficient

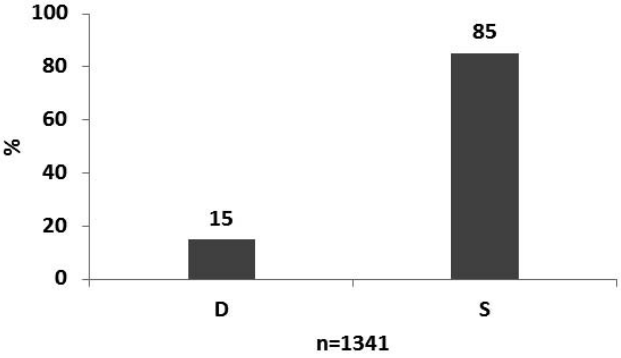

Fig. 17. Frequency of available zinc classes: D-Deficient, S-Sufficient

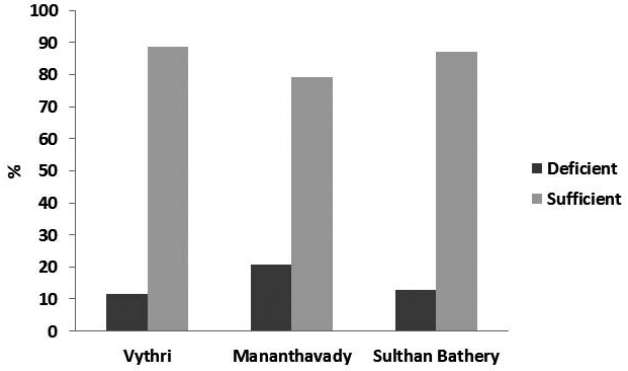

Fig. 18. Per cent distribution of soils of taluks under different available zinc classes

The per cent distribution of soils under the deficient (<1 mg kg^{-1}) and sufficient (>1 mg kg^{-1}) classes is presented in Figure 19. As the organic matter status of soils in Wayanad district is in medium to high range, deficiency of Cu is unlikely.

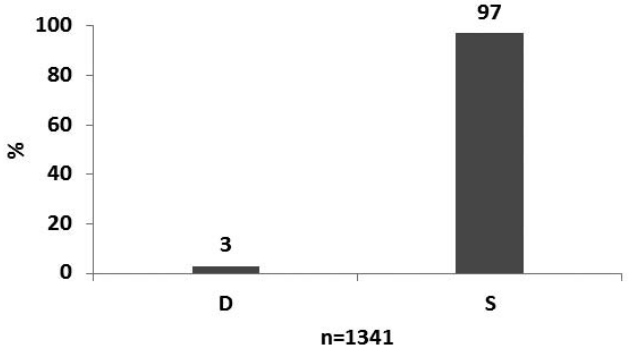

Fig. 19. Frequency of available copper classes: D -Deficinet, S-Sufficient

The analysis of the data over the different taluks of the district is presented in Figure 20. It was found that in all the three taluks, the soil samples were supplied with adequate quantities of Cu ranging from 96 to 99 per cent. Only negligible (1 to 4) per cent of soil samples were deficient with available Cu content. In Wayanad district, the robusta coffee is diversified with areca and pepper. Hence, use of fungicides to combat many fungal diseases of crops like arecanut and pepper in humid areas might have been the resaon for sufficiency of the element, which will be retainined in the soil organic matter inturn ensuring adequate levels of copper in soils. Foliar spray of properly neutralized copper sulphate solution can be recommended when deficiency of the nutrient is revealed in soil test data.

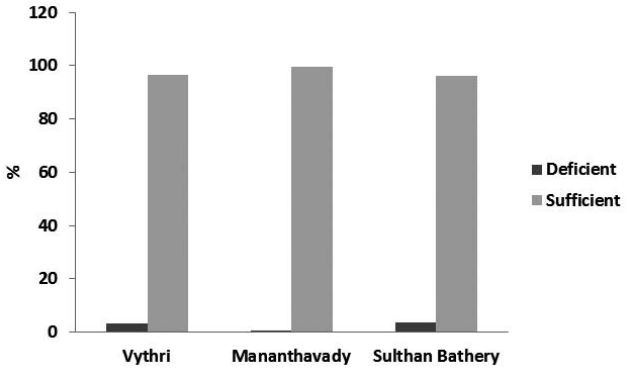

Fig. 20. Distribution of soils of taluks under different available copper classes

Available boron in soils

Boron (B) is known to play an important role in cell wall formation, pollen germination, flowering and fruit set. Deficiency of B is noticed as discolouration in young leaves of coffee and the terminal buds die under acute deficiency. Other symptoms of B deficiency include reduction in internodal distance and 'rosetting' of leaves.

Examination of the soil test data of 1341 samples belonging to Wayanad district for the available B content indicated the deficiency in 31 per cent of the samples only and the availability ranged from 0.02 to 1.52 mg kg^{-1}. The per cent distribution of soils under the deficient (<0.5 mg kg^{-1}) and sufficient (>0.5 mg kg^{-1}) classes is presented in Figure 21.

The data on the available B content in soils representing taluks was examined and found that B deficiency is spread into all the three taluks equally and the percentage of deficient soils ranged from 30 to 36 per cent (Fig. 22). Due to high level of P in soils, soil application may not ensure plant uptake of B. To correct the deficiency of B, foliar

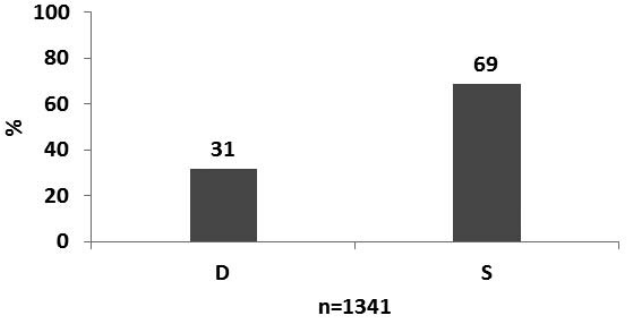

Fig. 21. Frequency of available boron classes: D-Deficient, S-Sufficient

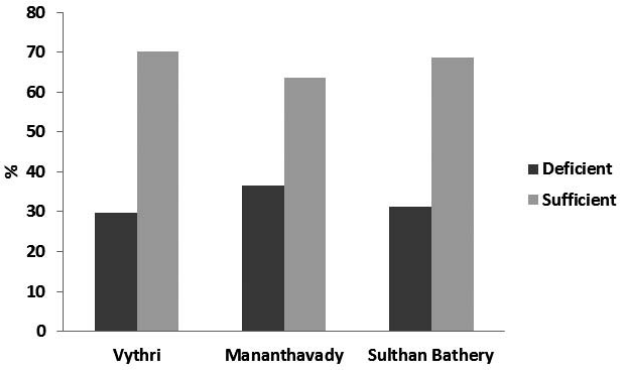

Fig. 22. Per cent distribution of soils of taluks under different available boron classes

spray of 0.3% boric acid or 0.5% borax can be recommended.

Recommendations on soil fertility management

1. Soil acidity is found to be to be a major constraint in Wayanad to achieve sustainable coffee yields as 98 per cent of the soils recorded acidic soil reaction while 69 per cent soils exhibited pH below 5.5. Hence soil test based liming programme need to be recommended to the growers to correct the soil acidity and improve the productivity of coffee in Wayanad.
2. Organic carbon content of majority of the soils cropped to coffee in Wayanad district is found to be in medium to high range. For the soils deficient in organic carbon (<1 per cent), application of 5 kg of compost/farm yard manure/organic manure per plant is recommended.
3. Reduction in P fertilizer doses to the soils with high P build up can be suggested. This will not only cut down the cost of cultivation but also will provide balanced nutrients to plants.
4. Available K status of soils of Wayanad district was fairly good and less number of samples was deficient in K. K fertilizer dose can be increased in the K deficient soils and split application may be recommended to ensure adequate supply of the nutrient to the plants.
5. To improve the fertilizer use efficiency of the low activity clay soils that are cropped to coffee, application of specified quantities of N and K fertilizers in as many splits as feasible can be adopted.
6. Deficiency of Mg was more prominent than calcium and sulphur in soils of Wayanad district. Application of good quality dolomite lime is recommended in Mg deficient areas. To correct the acute deficiency of Mg, foliar spray of 0.5 per cent magnesium sulphate is suggested.
7. For balanced supply of Ca and Mg to soils, application of calcitic (calcium carbonate) and dolomitic (calcium magnesium carbonate) lime in rotation is recommended in alternative years for application.
8. As available S is deficient in about 39 per cent of coffee growing soils of Wayanad district, foliar spray of 0.5 per cent magnesium sulphate is suggested to correct the deficiency.
9. The soils of Wayanad district were found to be well supplied with the micronutrients like Fe, Mn, Cu and Zn. In case of the soils being deficient in these nutrients, foliar sprays suggested.
10. Available B content was found to be deficient in 31 per cent of the soils cropped to coffee in the district. For coffee planted in the B deficient soil, foliar spray of 0.3 per cent boric acid or 0.5 per cent borax is suggested to provide adequate B supply to the plants.
11. To conserve the inherent fertility of topsoil, the planters in Wayanad need to be advised to abandon the farm operations (like scraping, scuffling and cover digging) that disturb the top soil in established plantations. Otherwise it will lead to the loss of fertile top soil through erosion and deterioration of soil health which can prove to be a major constraint in sustaining crop production.

Conclusions

Prolonged higher acidity of coffee soils with low to medium level of P, deficiencies of Ca, Mg and B have limited the coffee productivity in the district. Vast area of coffee in the district is acidic due to lack of liming and continuous use of acid forming fertilizers. Fifty per cent of soil samples were high in P which in turn impair nutrient balance and affects micronutrient absorption by plants. Deficiency of

Ca and Mg affects uptake of other nutrients in turn effect cellular functions. In coffee, B deficiency will affect the productivity by affecting flowering and fruit set. Amelioration of soil acidity and optimal use of major, secondary and micronutrients are must to enhance coffee productivity in the district. Based on soil test values, application of manures and fertilizers will save the fertility and also sustain the soil health. Integrated management of plant nutrients is essential to achieve sustainable coffee production.

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