Research Article

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Build up of soil phosphorus in coffee plantations of Karnataka over three decades

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Abstract

Karnataka is the largest coffee producing state in India contributing 72.3 per cent of the total production of the country. Arabica coffee is being cultivated in Karnataka in an area of 1.1 lakh ha and Robusta coffee in 1.2 lakh ha. Coffee growing soils are deep, friable, rich in organic matter, high in potassium content, well drained and slightly acidic in reaction. These soils contain large quantities of aluminium and iron oxides. Hence, phosphorus (P) availability in the Indian coffee growing soils is a constraint as the aluminium and iron oxides fix the applied phosphorus. Soil testing laboratories (STLs) of Coffee Board are rendering advisory service to the growers based on soil analysis and classify the data into low, medium and high category. In order to know the impact of the lime and fertilizer management on the soil available P status of the coffee growing soils of Karnataka, the soil-P data were compiled and classified into different categories for the 3 districts, *viz.,* Chikmagalur, Hassan and Kodagu for a period from 1980-81 to 2015-16. The decade-wise data set on soil available phosphorus so obtained was analyzed and the changes occurred over a period of time were assessed.The results indicated that over a period of thirty six years clear cut shift has taken place from low to high category in the available P status of soils cropped to coffee. About 50 per cent of the samples were low during 1980s while this has reduced to 42 per cent during 1990s and further reduced to 23 per cent during 2016. On the other hand the percentage of samples under high category has gradually increased from 24 to 51.

Keywords: Acid soils, coffee, P release, phosphorous buildup

It is well known that nutrient availability is influenced by their distribution in the soil as well as other soil characteristics. Soil test based nutrient management will help in sustained crop productivity without causing damage to the environment. After the green revolution in India, the use of NPK fertilizers increased in all the agricultural crops including coffee. Nitrogen and potassium applied to the soil will be subjected to loss through leaching during heavy rainfall while phosphorus will be converted to other insoluble forms and thus there is chance of accumulation in the soil. Phosphorus readily reacts with iron, aluminum and manganese compounds forming insoluble phosphate precipitates in acid soils. During this process P changes from readily soluble forms into sparingly soluble forms, thus restricting the availability to the plant. In India, coffee is being cultivated in slightly acid soils with major constraint of P precipitation, retention and adsorption. Hence, about 80-85 per cent of the applied P remains unutilized by the crop. In plantation crops like coffee, continuous application of P fertilizer may lead to P build up over a period of time. The present study was undertaken to assess the changes taken place in available P status in the soils of coffee plantations in Karnataka.

Materials and methods

Soil testing laboratories of Coffee Board are rendering advisory service on nutrient management to the growers based on soil analysis. There are two STLs situated at Central Coffee Research Institute, Coffee Research Station, Chikmagalur and Regional Coffee Research Station, Chettalli, Kodagu district in Karnataka. On an average about five thousand

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Table 1. Total number of soil samples analyzed in Karnataka State from 1981 to 2016

Year	Chikamagalur	Hassan	Kodagu	Total
1980-1981 to 1989-1990	19380	8334	6297	34011
1990-1991 to 1999-2000	20066	4061	6347	30474
2000-2001 to 2009-2010	25671	8725	22606	57002
2010-2011 to 2015-2016	15195	4619	12890	32704
Total	80312	25739	48140	154191

soil samples received from the growers of Karnataka are being analyzed for soil reaction and nutrient status every year and recommendation on requirement of lime as well as nutrient management are rendered to the growers. A total of 34011, 30474, 57002 and 32704 soil samples were analyzed for available P status in Karnataka State during the period 1980-81 to 1989-90, 1990-91 to 1999-2000, 2000-01 to 2009-10 and 2011 to 2016, respectively (Table 1). The data on the soil available P for the last three decades were classified into low, medium and high category. Decade wise data from 1980-81 to 2015-16, on soil available P was compiled and the changes occurred over a period of time was assessed and analyzed.

Results and discussion

The available phosphorus status of the coffee growing areas of Karnataka during 1981 to 1990, and during 2011 to 2016, is presented in Fig. 1. The results indicated a shift in the soil available P status of coffee plantations from low to high category. About 50 per cent of the samples were low during 1980s while this has reduced to 42 per cent during 1990s and further reduced to 23 per cent during 2016. On the other hand the percentage of samples under high category has gradually increased from 23 to 51 per cent.

A total of 80312 soil samples were analyzed for available P status in Chikamagalur district during the period 1980 to 2016. Decade wise number of soils analyzed and classification of soils into low, medium and high category, based on available P status is presented in Fig. 2.

Results indicate that about 54 per cent of the soils were low (<9 kg ha^{-1}) and 23 per cent were high (>21 kg ha^{-1}) in P status during 1980s. The percentage of soils classified as low has gradually decreased over next two decades to 44 and 28 respectively. Soils analyzed during 2011 to 2016,

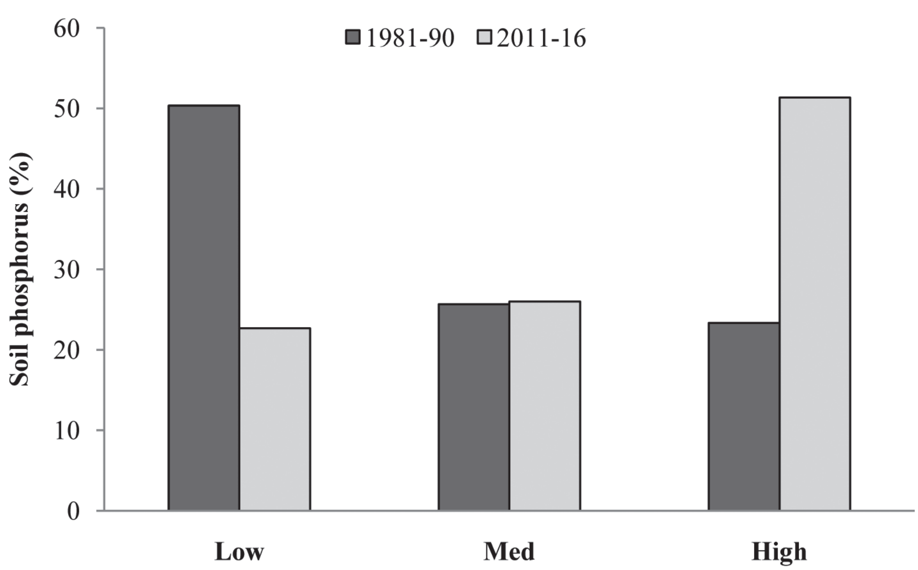

Fig. 1. Improvement in available soil phosphorus status of Karnataka State from 1981 to 2016

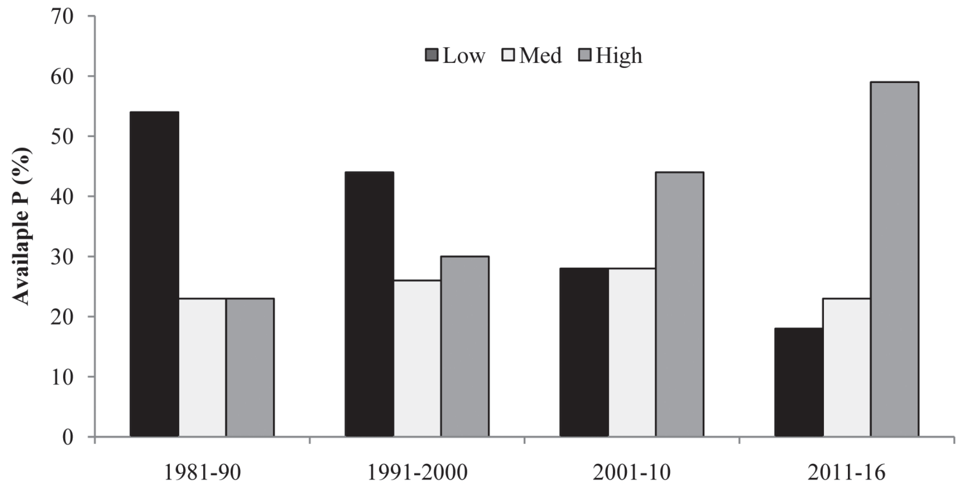

Fig. 2. Classification of soils based on available P status in Chikamagalur district

indicated that only about 18 per cent of the soils were under low P category. On the other hand, a reverse trend was observed with respect to soils classified as high. During 1981 to 1990, about 23 per cent of the soils were high with respect to available P and it increased gradually to 59 per cent during 2011 to 2016. There was not much difference in the medium category which ranged from 23 to 28 per cent.

Similarly, in Hassan district, about 59 per cent soil samples were low with respect to available P during 1981-90, while only about 18 per cent of soils were classified under low category during the period from 2011 to 2016. Consequently, during the same period, the number of soils having higher availability of P increased from 19 to 57 per cent in Hassan district (Fig. 3).

Similar trend was also noticed in the soil analysis results of Kodagu district. About 38 per cent of soil samples were classified under low category during 1981 to 1990, while during 2011 to 2016, number of soil samples falling in the low available P category reduced to 32 per cent (Fig. 4).

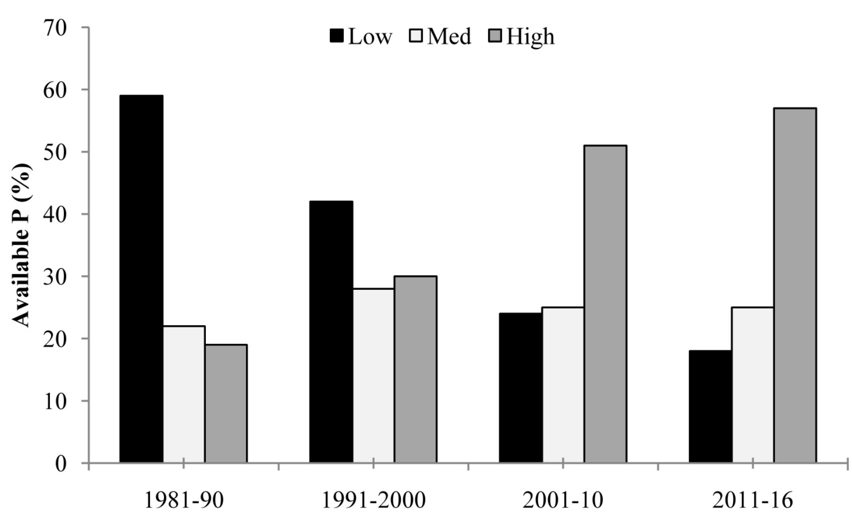

Fig. 3. Classification of soils based on available P status in Hassan district

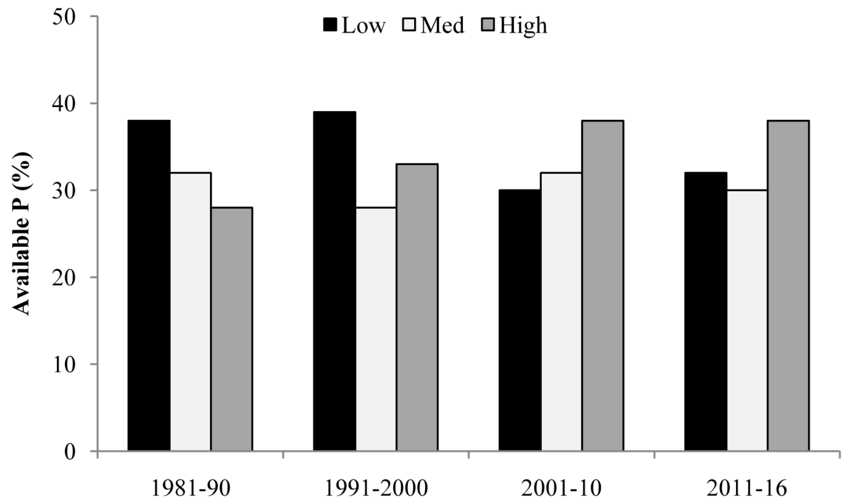

Fig. 4. Classification of soils based on available P status in Kodagu district

The coffee soils are generally well supplied with potassium but are low in available phosphorus (Anon.1985). The comparison of the analysis done over a period of thirty six years indicates that there is a need to reconsider the above statement as majority of the samples analyzed during 2011 to 2016, is classified under high category.

The analysis of the data on soil phosphorus indicates that, over the years, the phosphorus build up is increasing in soils cropped with coffee. This may be due to continuous application of P fertilizers to coffee plantations. Normally coffee growers apply NPK fertilizers in two to three splits, annually. Application rate of phosphorus ranges from 90 to 120 kg $ha^{-1}year^{-1}$. During 1980s, use of straight fertilizers like urea, rock phosphate and muriate of potash used to be popular source of fertilizer in coffee plantations. Application of water insoluble rock phosphates was found to be much cheaper during those days, than application of water soluble P fertilizers like DAP and complex fertilizers. Consequent to deregulation of P and K fertilizers during 1995 onwards resulted in the surplus availability of P and K fertilizers in the market. The price difference between (90 kg ha^{-1} P for one tonne of clean coffee) water insoluble rock phosphate and complex fertilizers like DAP has narrowed down over the years. During the same period, the availability of Mussoriephos has stopped due to the closure of the company. As a result of this many growers switched over to application of water soluble P fertilizers like DAP. This might be one of the reasons for observing high P build up in coffee soils. Similar observations (Anon. 1986) were made during 1966-67, that over 65000 soil samples analyzed during the decade revealed that soils were poorly supplied in respect of this nutrient. The samples analyzing low were found to an extent of 71 per cent by 1966-67, which was found to decline to around 49 per cent by 1971-72. Nath (2013) also observed in tea cultivation that available P content increased significantly in all tea cultivated soils, demonstrating that organic matter highly significantly correlated to nitrogen, phosphorus and potash. Under highly weathered condition over long period of time and continuous application of fertilizer, soil phosphorus undergoes significant change both in chemical forms and its location in soil profile (Reddy *et al*., 1991; Iyengar *et al*.,1982).

It has been estimated that a ton of clean coffee removes approximately 40, 7 and 45 kg of N, P_2O_5 and K_2O in the case of Arabica while 45, 9 and 58 kg of N, P_2O_5 and K_2O in the case of Robusta respectively from the soil (Jayarama *et al.,* 1996). The results of the fertilizer trials conducted at CCRI have often given inconsistent results. The continuous harvesting of crop will deplete the soil of one or more elements and makes nutrient management difficult. The strategy for nutrient management in coffee must aim at providing a balanced and optimum supply of nutrients required for high yields. The studies conducted by Jayarama *et al.* (1993) noticed a positive relationship between coffee yield and soil potassium and phosphorus content. Kimew (1974) noticed a positive response for P application when the soil available P is less than 20 ppm. Reducing the dose of fertilizers wherever the soil test results are high has not adversely affected the yield. Raju and Rao (1977) investigated that there was an initial increase of 100 kg ha^{-1} of available P by liming the very strongly acidic soils having pH of about 4.2. This increase in P may be due to the hydrolysis of strengite and variscite by the added lime releasing phosphate ions to the soil solution.

Kavitha *et al.* (2015) investigated a significant positive correlation between available P and soil pH in coconut, rubber, nutmeg, banana, and in vegetables. The significant and positive correlation indicates that available P in these soils is regulated by the content of organic carbon and high soil pH. Jayarama *et al*. (1996) estimated that leaf litter of shade trees contributes 40-60 kg N, 30-33 kg P_2O_5 and 40-60 kg K_2O per hectare. The leaf litter contribution by these shade trees is estimated as 10 MT per annum per hectare, which is one of the source of high organic matter in the coffee growing soils.The decomposition of the organic matter also helps in release of fixed P. Application of Phosphorus Solubilizing Bacteria (PSB) or citric acid also helps in mobilizing the fixed P in the coffee soils (Shiva Prasad *et al*., 2005).

Interactions with P have been reported for boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). Soils with high P levels, (naturally or through buildup) should be monitored for a possible micronutrient interaction. Raju and Deshapande (1987) studied the phosphorus and zinc interactions and reported that phosphorus and zinc have an antagonistic interaction, consequently excess phosphorus inputs may bring about zinc deficiency. Similarly, Ravi Bhat and Sujatha, (2014) studied that zinc deficits in higher number of arecanut (84-97%) indicated the reduction in Zn uptake due to excess of P in laterite soils. Kavitha *et al.*(2015), found that phosphorus level was significantly high in arecanut (274 kg ha^{-1}), at the same time deficiency of Boron was severe in Thrissur district soils. Ravi Bhat and Sujatha, (2014) found that regression between soil P and soil boron (B) had negative relation in laterite soils, thus, nutrient interactions in soil affect the uptake of nutrients despite sufficient nutrient availability in arecanut plantation. Phosphorus/B interactions caused a reduced B absorption by corn seedlings grown in an acid soil high in P. Phosphorus/Cu interaction was found when high levels of P accentuated acute Cu deficiency in citrus seedlings.

The accumulation of phosphorus in soil over a period of time may lead to serious environmental problems. Phosphorus application as manure to agricultural soils in intensive livestock farming and arable cropping systems often exceeds P uptake by crops which could lead to P accumulation in soils, making them long-term diffuse sources of P loss to water. Hooda *et al*. (2001), showed that long term P application would decrease the P retention capacity of soils and increases the degree of soil saturation with P, which would result in environmentally significant P loss.

Conclusion

The study indicated there is gradual accumulation of phosphorus in soils cropped to coffee in Karnataka. Reducing the dose of P fertilizer wherever the soil test results are high is necessary for balanced nutrient management in coffee plantations and reducing the cost of cultivation.

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