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Weighted Average Method in Evolving the Nutrient Status of Soils Under Cropping Systems Involving Tuber Crops in AEU 3 and AEU 9 of Kerala

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Abstract

Agro ecological unit (AEU) 3 and AEU 9 are the two major tuber crops growing regions of Kerala cultivating tuber crops like cassava, yams and aroids mostly as intercrops in coconut gardens. Nutrient status of the soils of AEU's are determined for making proper fertilizer recommendation to avoid both under-use and over-use of nutrients thereby attaining monetary gain as well as soil health protection by avoiding excess nutrient application. In arriving at proper nutrient status of the soils of the AEU's, determining the weighted average nutrient status of the AEU's with respect to the mean nutrient status and area of the panchayats/blocks was found better. It can be more meaningful and realistic from the point of view of arriving at the fertilizer recommendation to crops cultivating in that AEU's. In this paper, as a prelude to formulate customized fertilizers for elephant foot yam (EFY) under intercropping in the coconut gardens of these two AEU's, the weighted average data on pH, EC, organic carbon (OC), available N, P, K, Ca, Mg, S, Fe, Cu, Mn, Zn and B based on the nutrient status of the soils collected from 43 and 161 panchayats and their respective areas under AEU 3 and AEU 9 were determined. The values for AEU 3 and AEU 9 respectively were 5.85 for both AEU's (pH), 0.291 and 0.310 dSm^{-1} (EC), 0.945 and 1.502% (OC), 61.97 and 69.27 kg ha^{-1} (available P), 213.96 and 295.87 kg ha^{-1} (available K), 113.32 and 600.16 ppm (exchangeable Ca), 37.53 and 114.99 ppm (exchangeable Mg), 5.07 and 21.46 ppm (available S), 3.94 and 5.68 ppm (available Zn), 0.698 and 0.816 ppm (available B), 1.79 and 3.79 ppm (available Cu), 101.20 and 64.66 ppm (available Fe) and 18.82 and 37.65 ppm (available Mn). The weighted average data of the two AEU's indicated drastic variation in the nutrient status between the two AEU's in the case of most of the parameters. The weighted average nutrient data of the two AEU's clearly indicated the suitability of the soils of both AEU's for EFY cultivation especially AEU 9 as they are rich in organic carbon as well as other essential nutrients. Moreover, this data formed a basis for fixing the theoretical optimum of soil test based nutrient recommendation to derive the practical optimum based on nutrient omission and nutrient level experiments in formulating the customized fertilizers for EFY.

Key words: Weighted average, nutrient status, agro ecological units, nutrient management, customized fertilizers

Introduction

Agricultural productivity and agro-biodiversity of an area are largely governed by the prevailing climate and soil qualities of land. The concept of agro-ecological delineations was developed by FAO (1976, 1978) with the strong emphasis on comparable agro-climatic parameters to delineate agriculturally potential areas suitable for particular crops or the combination of crops through which optimum production potential can be achieved. The agro ecology of Kerala State delineated based primarily on climate, geomorphology, land use and soil variability resulted in the formulation of five agro

ecological zones (AEZ's) and twenty three agro-ecological units (AEU's). The boundary of the AEU's corresponds to the administrative boundaries of panchayats. For the present study, two AEU's viz., AEU 3 and AEU 9 which comprised of the major tuber crops growing tracts of Kerala were selected.

Coconut palm (*Cocos nucifera* L.) has the characteristic of regular and consistent food supply to mankind throughout the year especially for Kerala, called as 'Kalpa Vriksha'. The unique growth habit of coconut palm (7.5 × 7.5 m spacing) provides ample opportunities for growing subsidiary crops in the interspaces of coconut, so that, coconut based inter cropping system is unique in the homestead gardens of Kerala. Tuber crops are performing as better intercrops in coconut gardens of Kerala and the yield level of intercrops are comparable with the productivity levels of these crops under mono cropping in the open situation. Tuber crops which are generally grown as intercrops in coconut gardens include cassava, yams, arrowroot and aroids like elephant foot yam, taro and tannia.

Since the soil characteristics of the AEU's are entirely different, the data on the soil fertility evaluation of all the panchayats under each AEU's needs to be taken as it is an important aspect in the context of sustainable agriculture (Singh and Misra, 2012). The mean nutrient status of each panchayat with respect to each soil property in proportion to the area of the panchayat forms the basis in arriving at the weighted average data which in turn can be a realistic estimate on the current fertility status of the soil of the AEU's. When this weighted average data forms the basis for fertilizer recommendations, it can definitely realize optimum yield in addition to maintaining optimum soil fertility for sustainable agricultural productivity. Moreover, the use of weighted average data can lead to judicious use of chemical fertilizers thereby reduce the cost of cultivation as well as minimize environmental pollution due to the imbalanced application of chemical fertilizers.

Materials and Methods

The methodology followed in determining the weighted average data of the two AEU's of Kerala viz., AEU 3 and AEU 9 for the purpose of evolving the major, secondary and micronutrients recommendation and finally the designed fertilizer mixture called the customized fertilizer formulations' is detailed below:

For experimental purpose, the primary soil analytical data generated by the Kerala State Planning Board (KSPB) under the project 'Soil based plant nutrient management plan for agro-ecosystems of Kerala' was utilized. ICAR-Central Tuber Crops Research Institute (CTCRI) was also a partner to this multi institutional project handled 22,000 soil samples of the two districts viz., Pathanamthitta and Kottayam. The soil test data on pH, electrical conductivity (EC), organic carbon (OC), available phosphorus (P), available potassium (K), exchangeable calcium (Ca), exchangeable magnesium (Mg), available sulphur (S), available iron (Fe), available copper (Cu), available manganese (Mn), available zinc (Zn) and available boron (B) of the different panchayats of the two AEU's were taken. In this study, the mean nutrient status of the blocks and municipalities by taking the average of each parameter of the panchayats coming under each blocks (mean status of each nutrient parameter of the block) was calculated. In each panchayat, a total of 200-350 farmers plots were selected and soil samples were collected and analysed for the above 13 chemical parameters. The mean data with respect to each parameter from these farmers' plots was taken as the average data of the panchayats for the nutrients analysed. Sampling from farmers' plots were made randomly and based mainly on cropping pattern and cropping intensity with respect to the major prevailing land use pattern of the panchayats.

Agro Ecological Unit (AEU) 3

AEU 3 is Onattukara sandy plain, delineated for the sandy plains extending in to the mid lands from coast covering 43 panchayats under eight blocks and two municipalities spread over two districts viz., Kollam and Alappuzha districts covering Karthikkappaly, Karungappally and Mavelikkara taluks. Climate is tropical humid monsoon type with mean annual temperature of 27.6^{o}C and rainfall of 2492 mm with sandy soil type which is coarse textured with immature profiles. The major land use is coconut plantations on uplands and rice in lowlands covering an area of 67,447 ha, which is 1.74% of the State. The soil is acidic and deficient in major plant nutrients with poor cation exchange capacity (CEC), low nutrient and water retention capacity. The soil data of 43 panchayats under 8 blocks and 2 municipalities were taken for the purpose of arriving at the weighted average data of this AEU. The eight blocks and two municipalities were

Bharanikkavu, Chavara, Haripad, Karunagappally, Kayamkulam municipality (MC), Mavelikkara, Mavelikkara MC, Muthukulam, Oachira and Sasthamcotta. The number of panchayats in each blocks, area of each blocks, the mean nutrient status of these blocks and municipalities and the weighted average data calculated for each of the above parameters are given in Table 1. GIS map of AEU 3 is shown as Fig. 1.

Agro Ecological Unit (AEU) 9

The agro ecological unit (AEU) 9 is south central laterites delineated to represent the mid land laterite terrain with typical laterite soils having short dry period. AEU 9 has 161 panchayats of mid lands extending to the districts of Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha, Kottayam and Ernakulam. The climate is typically tropical humid monsoon type with mean annual temperature of 26.5°C and the rainfall is 2827 mm. The soil is strongly acidic, laterite clay type with gravels underlined by plinthite. Mono cropped rubber and coconut intercropped with a variety of annual and other perennial crops is the major land use on uplands. For the present study, 41 blocks/municipalities were taken and the weighted average data is presented in Table 2. The GIS map of AEU 9 is shown in Fig. 2.

Weighted average is an average in which all the soil chemical parameters are multiplied with the total area before summing up to a single average value. It is an average in which each quantity to be averaged is assigned a weight where these weights determine the relative importance of each quantity on the average.

The area of the panchayats available in the official website of the local self government department of the Kerala State (lsgkerala.gov.in) was used to calculate the percentage (%) area of each block out of the total area of the AEU.

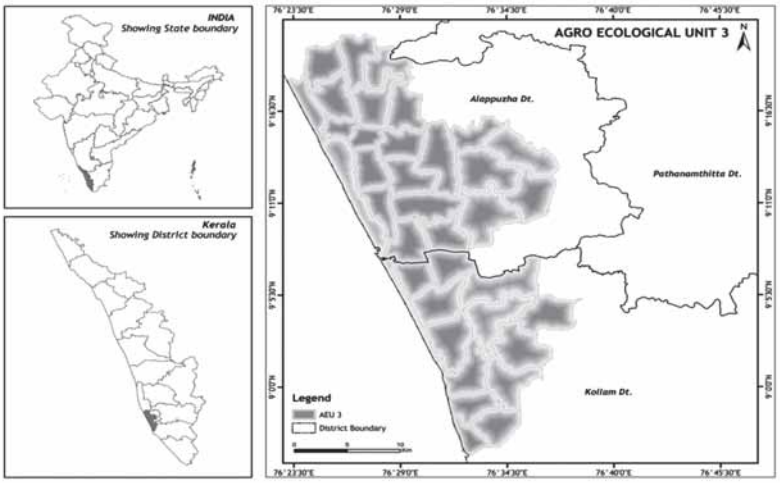

Fig. 1. GIS Map of AEU 3

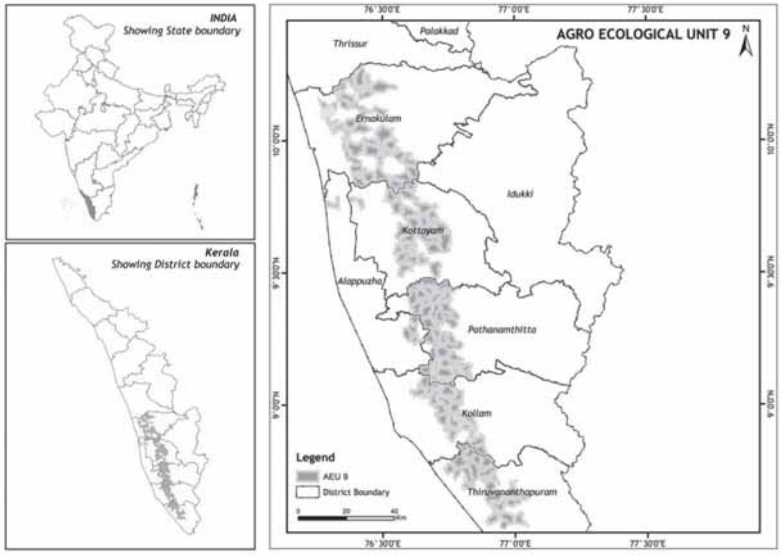

Fig. 2. GIS Map of AEU 9

$$\% \text{ area of the block in the AEU} = \frac{\text{Total area of the block}}{\text{Total area of the AEU}} \times 100$$

The weighted average data of each nutrient in each of the blocks were calculated by multiplying the mean value of the chemical parameter of each block with the percentage area of the selected block in the AEU and divided by 100.

Weighted average data of the chemical parameter of a particular block =

Mean data of the chemical parameter of the particular block × % area of the block in the AEU/100

By adding the weighted average data of the component blocks of the AEU, we arrived at the weighted average data for the particular parameter for that AEU (Fig.3)

Hence, this calculation of weighted average data of each chemical parameter with respect to the area is more realistic for evolving nutrient recommendation based on the nutrient status of the soil rather than the average value of each nutrients usually taken of a particular panchayat without taking into account the area of the panchayat.

Collection and analysis of soil samples from 250-300 farmers of each panchayat of the AEU's for chemical parameters viz., pH, EC, OC, P, K, Ca, Mg, S, Fe, Cu, Mn, Zn, B

↓

Determination of the mean value of each chemical parameter of the panchayat

$$= \frac{\text{(Sum of the values of the parameter of the independent farmers)}}{\text{Number of farmers}}$$

↓

Determination of the mean value of the chemical parameter of each block

$$= \frac{\text{(Sum of the values of the parameter of the component panchayats)}}{\text{Number of panchayats}}$$

↓

Determination of total area of the block by adding the area of all panchayats under the block

↓

Determination of total area of the AEU by adding the area of all blocks under the AEU

↓

Determination of % area of the block in the AEU

$$= \frac{\text{(Total area of the block} \times 100}{\text{Total area of the AEU)}}$$

↓

Determination of the weighted average data of the chemical parameter of a particular block =

Mean value of the chemical parameter of the block × % area of the block in the AEU / 100

↓

Determination of the weighted average data of the chemical parameter of the particular AEU

= Sum of the weighted average data of the chemical parameter of the component blocks under that AEU

Fig.3. Flow chart for the determination of the weighted average data of the nutrient parameters of the AEU's

Results and Discussion

As per the procedure outlined in the methodology, the weighted average data arrived for each chemical parameter of AEU 3 and AEU 9 by adding the weighted average data of each parameter of the component blocks of the two AEU's (Table1, 2) are presented in Fig.4 and 5.

The general soil critical levels of the chemical parameters viz., organic carbon, available P, K, Ca, Mg, S, Fe, Cu, Mn, Zn and B are 0.75%, 25, 280 kg ha^{-1}, 300, 120, 5, 5, 1, 3, 1 and 0.5 ppm respectively (KAU, 2012). Based on the soil critical level, we can understand whether the soils are deficient or sufficient in the particular chemical parameter while conclusions are arrived with respect to the weighted average data evolved.

pH as per the weighted average data of AEU 3 and AEU 9 was 5.85 indicating no difference between the two AEU's. As per KAU (2012), both the soils can be classified as moderately acidic (pH: 5.5-6) and the reason can be attributed to the humid tropical condition with sufficiently high rainfall causing the leaching away of metallic cations like Na, K, Ca, Mg leaving behind the Fe and Al sesquioxides creating intense acidity in the case of AEU 9. In AEU 3, one of the reasons for low pH can be due to the proximity to the sea and estuaries. Usually slight differences can be seen between the two AEU's which might be due the differences in texturals composition and particle nature of the soils.

Electrical conductivity (EC) is a measure of the soluble salts and is a measure of the cations and anions present in a soil which in turn is a measure of the salinity of the soil. Electrical conductivity of two

Table 1. Weighted average data of the chemical parameters of AEU 3

Blocks	Area	Number of pancha-yats	% area	pH	EC (dSm^{-1})	OC (%)	P	K	Ca	Mg	S	Zn	B	Cu	Fe	Mn
							(kg ha^{-1})		(ppm)							
Bharanikkavu	78.55	4	12.22	0.67	0.030	0.169	9.06	11.56	14.03	1.70	2.75	0.557	0.072	0.273	32.59	1.290
Chavara	74.90	5	11.66	0.80	0.024	0.082	7.15	10.26	11.04	2.31	0.21	0.378	0.075	0.180	4.68	1.161
Haripad	112.04	9	17.44	0.86	0.080	0.221	6.66	126.69	25.08	18.83	0.67	0.929	0.045	0.549	19.03	4.621
Karunagappally	66.34	4	10.32	0.60	0.020	0.083	9.15	15.58	12.11	2.55	0.18	0.698	0.088	0.176	3.97	1.022
Kayamkulam MC	21.79	1	3.39	0.22	0.002	0.009	1.57	4.13	0.96	0.13	0.26	0.149	0.058	0.048	0.67	4.940
Mavelikkara	67.97	4	10.58	0.48	0.020	0.154	3.74	8.38	0.75	3.14	0.03	0.424	0.075	0.094	24.10	1.359
Mavelikkara MC	19.82	1	3.08	0.17	0.010	0.018	1.62	4.45	3.36	0.16	0.02	0.149	0.030	0.101	1.25	0.590
Muthukulam	90.67	7	14.11	0.89	0.066	0.075	9.72	9.61	14.77	3.60	0.42	0.365	0.143	0.162	5.39	1.156
Oachira	70.68	5	11.00	0.68	0.015	0.074	7.58	14.57	16.52	2.83	0.31	0.160	0.059	0.100	6.10	1.674
Sasthamcotta	53.64	3	8.35	0.48	0.024	0.060	5.72	8.73	14.70	2.28	0.22	0.128	0.053	0.106	3.42	1.010
AEU 3 Mean	656.40	43	102.15	5.84	0.291	0.946	61.96	213.94	113.31	37.52	4.80	3.788	0.698	1.789	101.19	18.822

Table 2. Weighted average data of the chemical parameters of AEU 9

Blocks	Area	Number of pancha-yats	% area	pH	EC (dSm^{-1})	OC (%)	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
							(kg ha^{-1})		(ppm)							
Alangad	71.67	4	2.38	0.13	0.010	0.039	3.71	8.29	25.64	1.25	0.685	4.58	0.831	0.102	0.255	0.017
Angamaly	135.32	6	4.49	0.23	0.006	0.069	5.00	13.23	41.22	6.66	0.543	4.44	1.525	0.191	0.213	0.002
Chadayamangalam	71.08	3	2.36	0.14	0.007	0.037	0.68	7.44	4.74	0.98	0.727	0.72	0.657	0.034	0.071	0.009
Chengannur	42.60	3	1.42	0.08	0.001	0.018	0.492	3.56	8.05	0.19	0.004	2.86	0.943	0.140	0.087	0.000
Elanthur	106.22	7	3.53	0.19	0.005	0.053	3.24	9.84	17.38	2.40	0.686	1.35	1.303	0.101	0.194	0.062
Ettumanoor	27.81	3	0.92	0.05	0.003	0.012	0.64	2.75	4.43	0.48	0.227	0.21	0.263	0.035	0.046	0.007
Njeezhoor	28.91	3	0.96	0.05	0.016	0.010	0.91	2.44	3.75	0.32	0.643	0.55	0.599	0.034	0.047	0.012
Sreekariyam	20.73	3	0.69	0.04	0.001	0.008	0.16	1.52	1.17	0.20	0.172	0.16	0.079	0.012	0.044	0.001
Kilimanur	179.77	8	5.97	0.36	0.008	0.068	1.56	11.26	23.55	3.72	2.128	6.29	1.649	0.172	0.234	0.019
Koipram	124.41	6	4.13	0.21	0.010	0.079	2.41	12.82	31.00	6.53	0.918	1.52	1.839	0.141	0.179	0.037
Konni	18.66	3	0.62	0.03	0.001	0.008	0.53	1.60	1.16	0.34	0.155	0.21	0.187	0.016	0.024	0.002
Kottarakkara	132.67	6	4.41	0.26	0.007	0.049	2.27	3.64	10.06	1.89	1.527	0.78	0.535	0.060	0.162	0.085
Kulanada	60.05	3	1.99	0.12	0.006	0.028	1.73	5.75	14.96	4.89	0.318	0.66	0.756	0.073	0.148	0.012
Lalam	106.23	3	3.53	0.18	0.014	0.049	1.56	11.03	14.40	6.72	0.554	0.82	0.790	0.181	0.159	0.039
Vakathanam	26.48	3	0.88	0.04	0.004	0.012	0.91	3.22	2.32	0.55	0.220	0.30	0.202	0.028	0.048	0.009
Mallappalli	124.24	7	4.13	0.21	0.009	0.087	2.26	13.41	29.15	4.72	0.808	1.45	1.740	0.107	0.161	0.024

Mulamthuruthi	93.52	5	3.11	0.18	0.005	0.042	2.86	8.15	11.36	3.86	0.412	2.85	1.245	0.108	0.268	0.031
Chenganur MC	13.00	1	0.43	0.02	0.001	0.002	0.22	0.10	0.31	0.04	0.009	0.05	0.005	0.008	0.011	0.002
Kalamassery MC	27.00	1	0.90	0.06	0.002	0.007	0.96	2.06	5.94	0.06	0.106	1.14	0.241	0.044	0.131	0.005
Adoor MC	20.42	1	0.68	0.03	0.001	0.009	0.24	2.19	1.35	0.25	0.170	0.27	0.138	0.011	0.018	0.004
Attingal MC	14.18	1	0.47	0.02	0.001	0.002	0.13	0.46	1.92	0.23	0.068	0.59	0.230	0.028	0.010	0.001
Pala MC	15.93	1	0.53	0.03	0.003	0.008	0.34	1.77	2.56	0.94	0.132	0.17	0.122	0.032	0.032	0.003
Perumbavoor MC	13.52	1	0.45	0.03	0.001	0.007	0.51	2.07	4.03	0.83	0.041	0.08	0.137	0.014	0.077	0.001
Muvattupuzha	74.40	3	2.47	0.12	0.003	0.043	1.39	4.77	7.44	5.96	0.284	1.99	1.199	0.187	0.175	0.001
Nedumangad	123.50	5	4.10	0.26	0.013	0.050	1.02	20.08	16.74	2.23	1.253	6.34	1.735	0.166	0.195	0.020
Pallom	81.24	4	2.70	0.15	0.009	0.041	2.44	9.51	8.92	1.19	0.429	0.94	0.521	0.090	0.179	0.023
Pampakkuda	127.69	5	4.24	0.23	0.027	0.063	3.49	17.00	34.11	6.53	0.583	3.37	1.934	0.249	0.213	0.006
Pampady	138.52	5	11.45	0.59	0.048	0.193	7.40	41.15	64.97	13.38	2.285	5.06	3.849	0.493	0.677	0.078
Pandalam	55.65	4	1.85	0.09	0.003	0.028	0.76	4.23	6.86	2.96	0.445	0.82	0.261	0.048	0.051	0.003
Parakkadavu	63.38	3	2.11	0.12	0.004	0.024	2.01	6.88	29.92	4.23	0.299	0.43	0.429	0.025	0.129	0.002
Parakkode	185.09	6	6.15	0.33	0.009	0.082	4.55	11.99	37.39	3.18	1.173	2.70	2.126	0.197	0.329	0.107
Sasthamcotta	65.21	4	2.17	0.12	0.003	0.017	1.57	3.28	3.45	1.03	0.051	0.79	0.642	0.020	0.039	0.015
Kudappanakkunnu	10.61	4	0.35	0.02	0.001	0.002	0.05	0.30	1.06	0.25	0.065	0.15	0.100	0.011	0.009	0.001
Uzhavoor	125.26	5	4.16	0.21	0.013	0.054	2.40	11.62	14.53	5.82	0.985	1.43	0.935	0.144	0.158	0.018
Vadavukode	155.75	5	5.17	0.28	0.014	0.078	4.00	12.27	77.36	11.03	0.862	2.16	4.350	0.146	0.370	0.003
Viakkom	20.15	4	0.67	0.03	0.003	0.009	0.30	1.36	2.15	1.15	0.167	0.04	0.005	0.026	0.076	0.102
Vamanapuram	80.67	3	2.68	0.17	0.004	0.024	0.49	6.36	10.45	1.42	0.412	2.38	1.157	0.130	0.164	0.013
Varkala	27.01	4	0.90	0.06	0.020	0.010	0.14	2.50	3.09	0.94	0.159	1.00	0.332	0.022	0.034	0.003
Vazhakulam	67.19	5	2.23	0.12	0.004	0.033	1.71	5.79	9.72	2.98	0.408	2.01	1.042	0.111	0.168	0.002
Vazhoor	31.19	5	1.04	0.05	0.005	0.017	0.29	2.18	4.21	1.50	0.259	0.33	0.108	0.029	0.040	0.007
Vettikkavala	114.72	5	3.81	0.21	0.005	0.031	1.94	6.00	7.34	1.16	0.087	0.67	0.910	0.025	0.053	0.028
AEU 9 Mean	3021.65	161	107.20	5.87	0.31	1.50	69.28	295.88	600.14	114.96	21.459	64.66	37.653	3.789	5.680	0.817

AEU's was almost similar as 0.291 dSm^{-1} and 0.31 dSm^{-1} in AEU 3 and AEU 9 respectively and the soils are neither saline, sodic nor alkaline as per the critical limits of pH and EC delineated for characterising these soils into these groups.

The weighted average data of soil organic carbon (OC) in the two AEU's were 0.945 % (AEU 3) and 1.502% (AEU 9) respectively. The comparatively low pH in AEU 3 is in agreement with the findings of Beena and Jaya (2016) that, AEU 3 has lower OC per cent compared to laterite soils of AEU 9. The high OC in AEU 9 can be attributed to the high pool of soil organic matter and carbon rich soil type which prevent nutrient leaching making the minerals available to plants. Moreover, the high soil organic carbon can buffer the soil from strong changes in soil pH too (Leu, 2007).

Higher P availability was seen in the laterite soils of AEU 9 compared to sandy alluvial soils of Onattukara sandy plains of AEU 3. The major portion of Kerala soils has high P availability due to excess use of phosphatic fertilizers through factomphos which is manufactured in the State itself (Rajasekharan et al., 2014). Moreover, the immobile nature of P in the soil coupled with its low requirement compared to N and K also could be the reasons. Though more or less the same available P content in both AEU's was arrived based on the weighted average data, the comparatively high P noticed in AEU 9 over AEU 3 can be explained based on the findings of Tisdale et al., (1993) that, the high organic matter content in AEU 9 (1.502%) compared to AEU 3

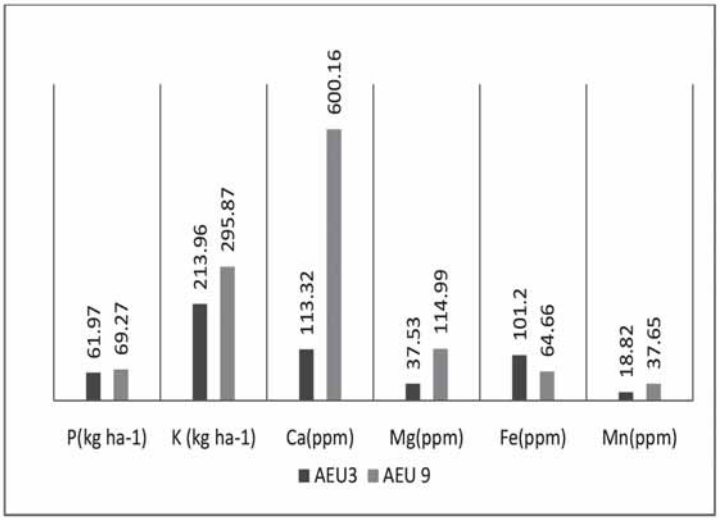

Fig. 4. Weighted average data of soil chemical parameters of AEU3 & AEU 9

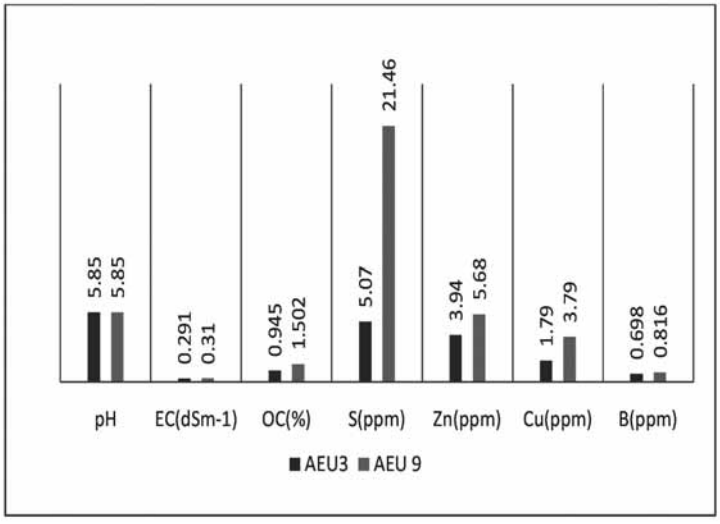

Fig. 5. Weighted average data of soil chemical parameters of AEU 3 & AEU 9

(0.945%) can prevent P fixation through the decomposition of organic matter which produces humus.

The weighted average data on exchangeable K revealed higher content in AEU 9 (295.87 kg ha^{-1}) than AEU 3 (213.96 kg ha^{-1}). This finding adheres to the reports of Rajashekharan et al., (2014), that, the K deficiency of Kerala soils are more pronounced in soils of coastal sandy and northern foot hills.

The exchangeable Ca content of both AEU's drastically differed to the tune of 113 (0.38 meq 100g^{-1} soil) and 600 (2.00 meq 100g^{-1} soil) ppm respectively in AEU 3 and AEU 9. In general, Kerala soils are low in basic cation contents especially K, Ca, Na and Mg. The tropical humid climate of this region receiving 200-300 cm rainfall causing the washing away of these cations resulting in highly acidic soils with low content of these nutrients. Nair et al., (2013), attributed it to the highly weathered nature of tropical soils. Further, the extremely low exchangeable Ca content in AEU 3 relates to the sandy texture of these soils permitting excess percolation and infiltration of water carrying these nutrients to the lower horizons of the profile.

As Magnesium being the central metallic cation in the chlorophyll molecule, playing a pivotal role in photosynthesis as well as an activator for many enzymes and nucleic acids required for plant growth, the soil status of this nutrient is very significant in plant nutrition. As in the case of K and Ca, the Mg content of Kerala soils are below the critical level indicating deficiency of this nutrient in Kerala soils. The Mg content in AEU 3 (0.313 meq 100g^{-1} soil) is far below that of AEU 9 (0.958 meq 100g^{-1} soil). It may be because of the nutrient holding capacity of AEU 9 due to high clay and organic matter content in these soils. The extensive deficiency of secondary nutrients viz., Ca and Mg in Kerala soils can be alleviated by liming and regular application of either dolomite @ 1 t ha^{-1} (Susan John et al., 2013) or $MgSO_4$ @ 80 kg ha^{-1} (Rajashekharan et al., 2014).

The S content in AEU 3 and AEU 9 was 5.07 and and 21.46 ppm respectively and found them well above the critical level of 5. The use of the complex fertilizer factomphos (N:P:K:S @ 20:20:0:13) which is manufactured in Kerala and widely available throughout the State resulted in sufficient S status in Kerala soils (Rajashekharan et al., 2014).

It is known that, micronutrients play a vital role in the metabolic processess of plant growth and yield. The weighted average data on the micronutrient status of the two AEU's indicated the status in both AEU's are above the critical level and hence found sufficient. It is seen that, compared to AEU 3, the content of these nutrients are high in AEU 9. There are previous reports indicating the deficiency of available Zn

in Kerala soils due to low organic matter and high available P content. Rajashekharan et al., (2014) already reported that, there was sufficient amount of Fe and Mn in Kerala soils, while 12% and 15 % respectively of Zn and Cu deficiency was seen in Kerala soils. From the studies of Rajasekharan et al., (2014) and Mini and Usha (2015), it is understood hat, B deficiency is prevalent in Kerala and to the tune of 85 % under AEU 3.

According to Benbi and Brar (2009), soil databases are immensely complex and the quality of the data is geographically diverse and these data can evaluate the overall effect of cropping and agricultural management on soil properties over the years, wherein the weighted average for each soil property needs to be calculated every year, if possible. Anju et al., (2020) estimated the weighted average data of the soil chemical parameters of AEU 3 and AEU 9 to arrive at the soil test based fertilizer recommendation (STBF) rate in the development of customized fertilizer formulations for elephant foot yam under intercropping in coconut gardens of Kerala.

Conclusion

During the initial years, chemical fertilizers were applied without any rationale. Later major nutrients like N, P, K were applied based on the NPK recommendation evolved as per fertilizer (NPK) rate trials considering the BC ratio the yield obtained. Afterwards from nineties onwards, thrust on soil health and its consequences on plant-animal-human continuum resulted in focusing on nutrient application based on soil test which in turn tell upon the available status of the nutrients present at that time. But the latest approach is to take care of both soil status and plant requirement to arrive at the fertilizer / nutrient application rate of primary, secondary and micronutrients. In this regard, research was initiated to develop fertilizer mixtures called 'customized fertilizer formulations'. As a prelude to the same, the initial step was to get a better understanding of the nutrient status of the soils for which the formulation will be developed. Here, we have taken the two AEU's of Kerala viz., AEU 3 and AEU 9 where tuber crops are mostly grown especially as intercrops in coconut gardens. As explained in the paper, the area of the panchayats / blocks/ AEU's too were considered to arrive at the weighted average data of the two AEU's instead of the usual methodology of taking the average of the nutrients alone. Evolving the mean nutrient status of the AEU's like this are more realistic and meaningful for providing fertilizer recommendations. These types of recommendations take care of all essential nutrients of plant growth including the limiting/constraint nutrients and sustain the yield and quality of the produce in addition to maintaining the physico-chemical and biological well being of the soil which can have both direct/ indirect reliance on plant, animal and human health and sustenance.

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