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Assessment of soil nutrient status of coconut gardens of East Kallada Panchayath of Kollam district, Kerala under the programme 'Kalparaksha': A compact area group approach programme on integrated crop management in coconut

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Abstract
Kerala state is known as God's own country which is widely known for beauty of coconut plantations and back waters. The name Kerala is from the word 'Kera' means coconut. However its cultivation is affected by various problems like soil related, pests and disease related, drought related etc. which leads to poor productivity. Soil related constraints include high acidity, toxicities of nutrients and deficiencies of nutrients. Nutrient management in coconut is a very difficult under soil limiting factors which is considered as highly significant because the palm entails a continuous supply of nutrients throughout the year for sustained productivity. Hence a balanced and integrated nutrient management is essential for enhanced productivity of coconut palms. widespread deficiencies of N, K, S, Zn, Fe, B etc. have emerged in many places of Kollam district and significant crop responses to application of these nutrients have been reported. Hence, evaluation of fertility status of the soils of an area is an important aspect in the context of sustainable agriculture. In this background, a study was undertaken at Krishi Vigyan Kendra Kollam Kerala Agricultural University, Kerala with an objectives to assess the fertility status of coconut growing tracts of East Kallada Panchayath of Kollam district of Kerala state and demonstrate soil test based nutrient application for enhancing the productivity of coconut from 2015-16 to 2019-20. Before the implementation of programme, soil samples were collected from the coconut gardens of participating farmers and analysed for pH, available macro and micro nutrients. The yield data from individual plots were recorded. Initial soil analysis revealed that 91.67% of samples were high acidic in nature. Most of the soils were low in organic carbon content and toxicities of P, Fe, Mn and deficiency of Mg and B were the other soil limiting factors. The farmers were advised to follow the soil test based nutrient management in the respective coconut gardens and supplied with chemical fertilizers for macro and micro nutrients. The study was constantly monitored and farmers were exposed to capacity building programmes on nutrient management for the entire project period (2015-16 to 2019-20). Soil samples were again drawn after the completion of programme (2019-20) and were subjected to analysis. It is evident from the study that the soil fertility status was increased. There was a reduction in the number of soil samples came under the category of severely acidic, low organic carbon content, deficiency of potassium, Mg and B. Due to the improvement in soil fertility, the final yield was also increased from 20 nuts per palm per year to 38 nuts per palm per year.

Keywords: coconut, soil test based nutrient management, integrated crop management, yield

Introduction
Coconut, the tree of heaven is grown in more than 80 countries of the world. India is one of the leading coconut producing country which occupies 15.46% of total area and 21% of production in the world. During 1960-61, Kerala shared 69.58% of total area and 69.52% production of the country but drastic reduction in area (760946.81 ha) and production (5299 million nuts) was observed during 2019 (FIB, 2021) [2]. Though coconut occupies 41% of total area of Kerala, the average yield of is very low (32 nuts /tree). The actual yield realized by the farmers from coconut is only 30-40% of the potential yield which was reported under ideal management conditions. The poor productivity is due to poor adoption of scientific management practices leading to the occurrence of pests, diseases and nutrient deficiencies. The coconut palms removes large quantity of nutrients from soils and it varies from 20 to 174 kg N, 2.5 to 20.0 kg P_2O_5 and 35 to 49 kg K_2O ha^{-1} (Ouverier and Ochs, 1978) [17]. The nutritional balance is indispensable to attain a sustainable yield (Reddy *et al*., 2002) [18].

Coconut is cultivated under extremely varied soil conditions like coastal sand to clay, from poorly drained uplands to hill slopes and strongly acidic to highly calcareous soils (Khan *et al*., 1978) [11]. Nutrient management in coconut is a very difficult under soil limiting factors which is considered as highly significant because the palm entails a constant supply of nutrients throughout the year for high productivity round the year (Khan, 1993) [12]. Hence a balanced and integrated nutrient management is essential for enhanced productivity of coconut palms. Restoration of soil fertility and productivity is possible by following integrated nutrient management which ensures the nutrients availability in right quantities, in right form and at right time (Mohandas, 2012 [13]; Nadheesha and Tennakoon, 2008 [14]). Improper soil management leads to poor soil fertility coupled with the soil erosion through which nutrient rich soil is lost. Continuous cropping removes huge quantity of nutrients from the soil.

Nutrient deficiencies mainly N, K, S, Zn, B etc. have been reported in Kollam district by Nair *et al*., (2013) [15]. External application of these nutrients to crop resulted to enhancement of yield in many crops. Hence, assessment of soil fertility status of an area is highly important in the context of sustainable agriculture (Singh and Misra, 2012) [19]. Soil testing is widely accepted as scientific method to assess inherent power of soil to supply plant nutrients. Appropriate application of fertilizers enhances crop yield whereas unnecessary use may be harmful to the environment (Ganorkar *et al*., 2017) [3]. Hence, appraisal of soil fertility status of farmer's field is of prime importance for a balanced application of fertilizers and manures as well as reduces the wastage of nutrients. The soil nutrient reserve decides the nutrient supplying capacity which is the primary factor to be considered for deciding the amount of nutrients to be added to soil for crop production. Hence, soil test based nutrient management has emerged as a key step to increase agricultural productivity and production through the ideal use of nutrients. Since the information on soil testing of many farmers field are lacking, it is imperative to make aware on soil testing among farmers for a sustainable crop production. Soil nutrient management according to soil test results surely enhance yield by improving the crop health. With this background, the study was conducted as part of the Kalpaksha programme of KVK – Compact area group approach for the integrated management of coconut to enhance the productivity of coconut through scientific crop management practices in a compact area with good public participation. Hence, present study was undertaken at Krishi Vigyan Kendra Kollam Kerala Agricultural University, Kerala with an objectives to assess the fertility status of coconut growing tracts of East Kallada Panchayath of Kollam district of Kerala state and demonstrate soil test based nutrient application for enhancing the productivity of coconut.

Materials and Methods

Study area

The study area was selected as per the criteria viz., area where coconut was grown as a major crop and poorly managed coconut gardens where more prevalence of yield reduction factors *viz* pest, diseases, high acidity, and nutrient imbalance. In consultation with Department of Agriculture and Farmers Welfare, in East Kallada panchayath, 5.6 ha of coconut gardens belonging to 60 farmers of Thekkamuri ward was found ideal for intervention since coconut was the major crop and almost all problems of coconut were prevalent there. Out of this, 1.13 ha was covered under Kendra's frontline demonstrations on Integrated Crop Management in coconut and rest under Agriculture Technology Management Agency of Kollam district. The area came under the agro ecological unit (1) ie., Southern coastal plain where coconut based cropping system was more predominant in the Chittumala taluk of Kollam district. This agro ecological unit experiences a climate of tropical humid monsoon mean annual temperature 27.6^{0} c and rainfall 2360 mm. Soil moisture was generally suitable for crops from mid April to third week of December. Coconut plantations on upland and rice in lowlands are the major land use. The unit covers 56,782 ha (1.46%) in the state.

In East Kallada panchayath, 5.6 ha of coconut gardens belonging to 60 farmers of Thekkamuri ward found ideal for intervention since coconut was the major crop and almost all problems of coconut were prevalent there. Out of this, 1.13 ha covered by Kendra's FLD on ICM coconut and rest by ATMA

After selecting the area, meeting with local leaders viz panchayath president, ward member and agricultural officer was done. Another meeting with participating farmers and KVK scientists farmers along with the local leaders and Krishibhavan officials was done for explaining about the program and ensuring public participation. A survey was conducted in the area for understanding the present situation with the help of a questionnaire. Panchayath president was the chief patron of the program. Farmers were divided in to 5 groups for carrying out all the activities in each area. A captain and a vice captain was elected for these groups. A monitoring committee consisted of captains, vice captains of all groups, scientists of Krishi Vigyan Kendra, agricultural officer and ward member. This committee met once in a month to assess the progress, there was a pre and post monthly meeting in each group. After completing the survey, all farmers were given registers for documenting the details of palms besides giving registers to group leaders. The palms were marked with paint and all the palms were numbered. Problems of each palm were recorded in the farmers register and groups register, palms to be lopped were also recorded

Soil sample collection analysis

Representative composite soil samples were collected from 60 farmers' fields of selected area of East Kallada panchayath during March 2015-16 from a depth of 30cm at 180 cm away from the bole of coconut palm. These samples were air dried under shade for about 24 hours and grinded with the help of pestle and mortar and sieved the entire quantity of soil through 2 mm stainless sieve. Then the soil samples were subjected to analysis. After the successful implementation of programme 'Kalparaksha" the soil samples were collected again during the year 2020 for the analysis.

The soil samples were analyzed for 13 parameters viz, pH, EC, organic carbon, available phosphorus, potassium (macro nutrients), Ca, Mg, S (Secondary nutrients), and micronutrients (Fe, Mn, Cu, Zn and B). The parameters *viz* pH, electrical conductivity (EC) organic carbon, available phosphorus, available Potassium,Sulphur available Fe, Mn, Zn and Cu and B were analysed following standard analytical procedures (Jackson, 1973) [8]. To evaluate the fertility status, estimated values of various parameters were classified into low, medium and high based on the specific rating chart (Crops, 2016 [10], ICAR, 2011 [5], Olesen and Dean [16], 1965 and Jacob *et al*., 2015 [6]**)**. The yield from individual palms were recorded with the help of participating farmers before and after the programme**.**

Table 1: Classification of soil based on pH

Sl. No.	pH range	Class
1	<3.5	Ultra acid
2	3.5-4.5	Extremely acid
3	4.5-5.0	Very Strongly acid
4	5.0-5.5	Strongly acid
5	5.5-6.0	Moderately acid
6	6.0-6.5	Slightly acid

Table 2: Rating chart for levels of Organic carbon and other nutrients in soil

Soil parameters	Unit	Low	Medium	High
Organic carbon (OC)	%	<0.4	0.4-0.75	>0.75
Available phosphorus (P)	kg/ha	<16	16-45	>45
Available potassium (K)	kg/ha	<135	135-335	>335
Calcium (Ca)	mg/kg	<240	240-300	>300
Magnesium(Mg)	mg/kg	<96	96-120	>120
Sulphur(S)	mg/kg	<10	10-16	>16
Iron (Fe)	mg/kg	<4.5	4.5-9.0	>9.0
Manganese (Mn)	mg/kg	<3.5	3.5-7.0	>7.0
Zinc (Zn)	mg/kg	<0.6	0.6-1.2	>1.2
Copper (Cu)	mg/kg	<0.2	0.2-0.4	>0.4
Boron (B)	mg/kg	<0.2	0.2-0.4	>0.4

Continuous monitoring and management of coconut palm from 2015-16 to 2019-20 were done with the help of monitoring committee. After the completion of the programme (2019-20) samples were drawn again and subjected to analysis. The observation on yield before and after the implementation of the programme was recorded. Both the pre and post soil analysis data were subjected to statistical analysis (paired t test) using GRAPES 1.0.0 -a web application developed by Gopinath *et al*. (2021) [4]. Means were compared and p-value was found out to find the significance between 2 population means. Frequency and percent of samples under low, medium and high category were also found out.

Results and Discussion

The soil test data are presented in the table 3, 4 and 5 which are interpreted below.

Soil pH

Soil acidity is one of the key reason leading to poor soil productivity in Kollam district as most of the soil are laterite in nature. Before the implementation of the programme 'Kalparaksha', all soil samples analysed were of acidic in reaction with 91.67% of samples were come under extremely acidic to very strongly acidic (pH<5.0). Soil test based lime application was done to neutralize the acidity continuously for 2019-2020 to improve the soil health condition. After the implementation of the programme, the samples were analysed during the year 2019-20, the results showed that only 60% of soil samples were tested as below the pH of <5 indicating the continuous application helped the farmers to improve the soil reaction ie., number of samples came under the category of extremely acidic to very strongly acidic was reduced while the number of samples came under the category of moderately acidic and slightly acidic range were increased.

Organic carbon

In general the status of the organic carbon was low to medium ranging from 0.06% to 0.90% during both period of study *ie.*, before and after the implementation of the programme which indicated that even after the continuous application of the organic manure as per the soil test basis there was very scanty rise in organic status of the soil. Organic carbon is essential for soil health as it provides plant nutrients, improves soil structure, water infiltration and retention in addition to this, it acts as a feed for soil micro flora and fauna (Johnston, 2007) [9]. Before the implementation of the programme a greater number of soil samples (65%) were tested for its low organic carbon content while the percent of soil samples came under the low category was reduced after the continuous application of organic manure *ie*., after the implementation of the programme. Even though a significant difference was observed between the population mean before and after the implementation of the programme, the organic carbon status was not much enhanced due to application. This may be due to the rapid rate of decomposition of organic matter due to high temperature. As a result the increase of organic matter in soil is not taking place. It is very essential to add organic manures periodically.

Available Phosphorus

Phosphorus is an essential nutrient which is required for energy storage and energy transfer (Jain *et al*., 2014) [7]. This is also required for root, seed, and fruit development. Under the study, available phosphorus status of soil was found to be very high during the both time of study ie., before and after the implementation of the programme. It was seen that there were no samples tested as deficient in this area and high proportion of soil samples tested for excess levels of phosphorus. The available P content varied from 12.2 to 36 kg per ha in the initial soil samples and 29.1 to 86.5 kg per ha in the final samples. Before the implementation of the programme it was observed that 11.67 and 88.33 percent of the samples came under the category of medium and high P class respectively while 60 and 40 percent of soil samples were tested as medium and high category respectively after the implementation of the programme. Continuous application of the phosphatic fertilizers increased the available P in the soil this was the probable reason for the high P status in the initial soil. Due to the interventions of KVK Kollam the blanket application of recommended dose of P fertilizers was reduced as per soil test data. The result showed the possibility of reducing the use of phosphatic fertilizers.

Available potassium

The nutrient potassium is essential for various enzymes activities of physiological processes, provides resistance to pests, diseases and drought. Available soil potassium content of the study area was found to vary from 34 to 448 kg per ha and 112 to 364 kg per ha during the initial and final period of observation respectively with a mean value of 139.467 kg/ha and 194.056 kg/ha during the initial and final year of study. The statistical analysis showed that there was significant variation between both the years. During the initial year (2015-16) ie., before the implementation of the project 48.33% of samples showed deficiency of potassium which suggested the regular application of potassium fertilizers based on soil test data to coconut. This deficiency may be due to increased content of Fe and Mn in soil which inhibited the K absorption and utilization by plant (Bridgit, 1999) [1]. Due to the heavy rainfall it was advised to apply K fertilizers in many split doses. After the project period, 2019-20 the soil samples were tested again which indicated the deficiency status of K was improved as evident from the data which indicated that only 31.67 percent of soil samples were deficient. During the initial year there was a low K content in the study area as the majority of soil samples was under the low range while the final analysis of soil sample revealed that the K content was increased (63.33%) with a medium K status. As the soils are dominant in sand with low content of 2:1 type of clay results in the leaching of K. The potassium retention capacity of these soils are also low. There is a lack of weatherable potassium bearing minerals.

Secondary nutrients

Calcium, magnesium and sulphur are the essential secondary nutrients. During 2015 the content of Ca in all soil samples tested except one were in the high range and one sample was diagnosed for Ca deficiency. The farmers of these region regularly apply lime as it is cheaply available in these areas. Ca status in the soil samples ranged from 320 ppm to 1260 ppm. Before the implementation of the project the nutrient magnesium was deficient in 81.67% of soil samples tested. 15% of soil sample tested were medium in Mg content. The farmers were advised to apply Magnesium sulphate @500g/palm/year regularly. The Kendra supplied magnesium sulphate also. Hence after the completion of the project the Mg content of the soil was tested again and found that a reasonable increase in magnesium. 71.67% soil samples tested for high Mg. It is necessary to apply the magnesium sulphate regularly in accordance with soil test data. During the both years no deficiency of S was recorded in any of the samples. The S content in the samples ranged from 10% to 31.5%. Among the samples during the initial and final years of the project 71.67 and 81.67 percent of samples were high in S which might be due to the wide spread use of NP complex fertilizer factumfose which contain S also.

Micro nutrients

The micro nutrients are required by plants in very low quantities even though these are essential for plant growth. The micro nutrients analysed include zinc, iron, copper, manganese and boron. The micro nutrients Fe, Mn and Cu were observed to be in high status. This might be due to the strong acidity of soil (Nair *et al*., 2013) [15]. The content of copper was high in all the soil samples tested which ranged between 0.5 to 1.8 ppm. Copper is lightly held by the exchange complex of soil might be the reason. The zinc content during both years was medium to high showing that there was no deficiency. During the year 2015 60% soil samples were medium in zinc content and 40 percent were high. After the completion of the project the soil samples with high Zn content was raised to 60%.

Boron was another essential micronutrient required only in very small quantities. Among the micro nutrients tested boron deficiency was more pronounced. Before the implementation 96.67 percent of soil samples tested for boron deficiency. Based on soil test data the KVK supplied boron containing fertilizers borax which contains 11.3% B and advised them to apply. Due to the regular application of borax the soil, boron status is gradually increased. After the successful completion of the project again boron content in the soil samples were tested and found that the boron deficiency was corrected as evident from the zero values in the table while all the soil samples tested fall under the category of medium (26.67%) to high range (73.33%).

Yield

The check yield was the initial yield received by farmers before the implementation of project. It was observed that only 20 nuts per palm per year was the initial yield. The yield was recorded after the successful implementation of the programme which showed an increase in the average yield. The yield increase happened here was mainly occurred due to the scientific management practices which includes soil test based nutrient application to the palms. Though we couldn't achieve the goal of 90 nuts/palm, though yield was not stabilized, almost all palms started to bear. Thus it is clear that with the adoption of scientific nutrient management, yield increase can happen in any existing plantation. In the fragmented land holdings, with the farmers' cooperation an area wide programme can be formulated and implemented to achieve this goal.

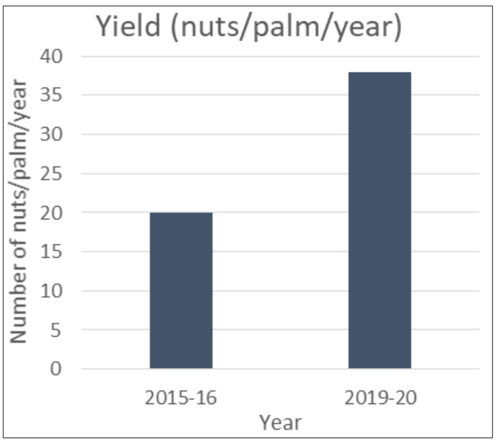

Fig 1: Yield of coconut (nuts/palm/year) before and after the implementation of programme

Table 3: Status of pH in plots before and after the implementation of programme 'Kalparaksha'

Nutrients	Year	Percent of soil samples					Concentration		p-value
		Extremely acidic	Very strongly acidic	Strongly acidic	Moderately acidic	Slightly acidic	Mean +/- SD	Range	
pH	2015-16 (Before)	21.67	38.33	31.67	8.33	0.00	4.890+/-0.470	4.1 to 5.7	0
	2019 -20 (After)	0	30%	30%	36.67	3.00	5.253+/0.441	4.2 to 6.7	

Table 4: Organic carbon, available phosphorus and available potassium status in plots before and after the implementation of programme 'Kalparaksha'

Nutrients	Year	Percent of soil samples			Concentration		p-value
		Low	Medium	High	Mean +/- SD	Range	
Organic carbon (%)	2015-16	36.67	60.00	3.33	0.430+/-0.173	0.06 to 0.90	3.9e05
	2019-20	30.00	65.00	5.00	0.465+/-0.150	0.06 to 0.82	
Available phosphorus (kg/ha)	2015-16	11.67	88.32	0.00	29.063+/- 6.453	12.2 to 36	0
	2019-20	0.00	60.00	40.00	48.188+/-19.866	29.1 to 86.5	
Available potassium (kg/ha)	2015-16	48.33	33.33	18.33	139.467+/- 87.340	34 to 448	0
	2019-20	31.67	63.33	5.00	194.056+/- 73.209	112 to 364	

Table 5: Secondary and micro nutrient status in plots before and after the implementation of programme 'Kalparaksha'

Nutrients (ppm)	Year	Percent of soil samples			Concentration		p-value
		Low	Medium	High	Mean +/- SD	Range	
Calcium	2015-16	1.67	1.67	96.67	587.5+/- 218.697	220 to 1260	0.0471
	2019-20	0	3.33	96.67	549.6+/- 199.086	300 to 1050	
Magnesium	2015-16	81.67	15.00	3.33	77.17+/- 45.346	24 to 378	0
	2019-20	0	28.33	71.67	120.683+/- 22.417	86 to 254	
Sulphur	2015-16	0	28.33	71.67	21.343+/-7.172	10.00 to 37.5	0
	2019-20	0	18.33	81.67	23.542+/- 6.614	12.3 to 38.6	
Iron	2015-16	0	0	100	30.903+/- 10.702	10.4 to 74.00	0.087
	2019-20	0	0	100	31.608+/- 11.127	10.4 to 75.6	
Manganese	2015-16	0	0	100	23.715+/-8.002	9.1 to 48.2	0.001
	2019-20	0	0	100	21.995+/-7.289	to 45.6	
Copper	2015-16	0	0	100	1.150+/-0.232	0.5 to 1.8	0.482
	2019-20	0	0	100	1.122+/-0.215	0.6 to 1.3	
Zinc	2015-16	0	60	40	1.155+/-0.368	0.6 to 2.5	0.228
	2019-20	0	40	60	1.308+/-0.902	0.8 to 1.9	
Boron	2015-16	96.67	1.67	1.67	0.096+/-0.065	0.02 to 0.4	0
	2019-20	0	26.67	73.33	0.332+/-0.117	0.17 to 0.53	

Conclusion

It is evident from the study that the main constraints in the coconut gardens of agro ecological unit 1 Southern coastal plain of Kollam district were high acidity, poor organic carbon content and toxicity of P, Fe, Mn and deficiency of Mg and B which were the main soil limiting factors decreasing the yield. Through the interventions of KVK -soil test based nutrient management in a compact area group approach, the farmers corrected these soil limiting factors. The recommendations of KVK for the yield enhancement in coconut for the agro ecological unit 1 (Thekkemuri ward of East Kallada) of Kollam district were regular application of dolomite, organic manures or recycling of coconut residue, application of magnesium sulphate and boron. The farmers were also advised to reduce the use of P fertilizers after observing the soil test data and apply all other primary and secondary nutrients in accordance with the soil test data. Regular monitoring by KVK scientists was done and capacity building programmes along with supply of different nutrients containing fertilizers were also conducted. The soil test data taken after the completion of the project period clearly revealed that the fertility of the region was improved. It was observed from the data that the nutrients which were deficient during the initial year was increased after the project period. Hence it can be concluded that soil testing and soil test based nutrient management are mandatory to improve the soil health which enhance the productivity. This can be achieved by conducting frontline demonstrations in a compact area group approach through farmer participation.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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