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SCIENTIFIC PERSPECTIVE OF BEST FARMERS' NUTRIENT MANAGEMENT PRACTICES FOR COCONUT (*Cocos nucifera*) IN KERALA

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Abstract- Field investigation through stratified random sampling was undertaken during 2010-11 in 53 high yielding coconut (*Cocos nucifera* L.) gardens located in 17 agro ecological units (AEUs) of Kerala, India to determine production potential of coconut, assess yield disparity between best and common farmer managed coconut garden and develop nutrient management plan based on best farmers' management practices. AEUs having high production potential were Onattukara Sandy Plain, Northern Laterites, Southern Laterites and Southern Coastal Plains with yields of 250, 208, 180 and 180 nuts/palm/year respectively. AEUs having low production potential were Kole Lands, Wayanad Central Plateau, Kuttanad and North Central Laterites with yields of 60, 86, 100 and 110 nuts/palm/year respectively. Yield disparity in AEUs varied from 36 to 987%. Proposed nutrient management plan involves application of 1 kg burnt lime, on farm composting with 60 kg organic manures comprising of 30 kg each green leaf manure and farm yard manure, application of 1 kg Factamfos, 0.5 kg muriate of potash, 1.5 kg common salt, 0.5 kg magnesium sulphate and 50 g borax to each palm every year.

Keywords- Agro ecological unit, Coconut, farmer, Kerala, nutrient index, nutrient management, organic manure, yield.

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Introduction

Kerala state had increased coconut production by 46% from 3981 million nuts in 1970-71 to 5799 million nuts in 2012-13. Productivity of coconut improved by 31% from 5536 to 7265 nuts/ha during the same period [1,2]. Factors like variety, irrigation, nutrient and other management practices along with support price had contributed to this progress. Effective nutrient management, which is estimated to contribute around 30% among critical inputs, is essential to continue the present pace of progress.

Kerala state is delineated into 23 agro ecological units (AEUs). Each AEU is a homogenous agricultural region with unique climate, soil and land form characterised by distinct responses to plant nutrients as evident in productivity of agricultural crops. Kerala state average production was 43 nuts/palm/year during 2011-12. In some AEUs, there had been undocumented reports of progressive farmers achieving productivity much higher than the state average. The yield potential of coconut had not been properly understood by coconut farmers and development agencies [3].

Researchers and administrators incessantly face the challenge of realising production potential of coconut in farmers' field. The present investigation was therefore undertaken to determine production potential of coconut in Kerala, assess yield disparity between best and common farmer managed coconut garden in each AEU and develop nutrient management plan for coconut based on existing best farmers' management practices in order to reduce yield disparity.

Materials and Methods

A field investigation was carried out in farmers' fields of Kerala state located between 8°18' and 12°48' N latitude and 74°52' and 77°22' E longitude. Production potential alternatively termed as best farmer yield (BFY) is the highest attainable yield of coconut in a given location. For determining production potential of coconut in Kerala, 17 agro ecological units (AEUs) were identified out of the total 23 AEUs and in these AEUs, 52 high yielding coconut gardens were identified through stratified random sampling. Yield of uniform stand of 50 selected palms in each high yielding coconut garden were recorded by adding total number of nuts harvested in each harvest for one year during June-May of 2010-2011. The highest yielding coconut garden in an AEU was identified as the best farmer managed coconut garden in that AEU and its yield recorded as best farmer yield (BFY). Coconut yield obtained by common farmer from their field located within the same panchayat as that of the best farmer's field was ascertained through local enquiry and recorded as common farmer yield (CFY). The following equation was used to assess yield disparity (YD) in each AEU.

$$YD = \frac{BFY - CFY}{CFY} \times 100$$

Where, BFY is best farmer yield and CFY is common farmer yield.

A group of 8 out of 17 best farmer managed coconut gardens was studied for level of nutrients in leaf, soil and fertilizers applied so that a nutrient management plan could be formulated [Table-1]. The four criteria followed for short listing this group were absence of supervision by government agencies, non-existence of T x D hybrid palms, presence of palms within age range of 20 to 60 years and yielding more than two and half times the average common farmer yield of 42 nuts/palm/year.

Leaf samples from index leaf of 4 representative palms in best farmer managed coconut gardens were collected [4,5], processed [6] and analysed for nutrients *viz*. Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S), Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu) and Boron (B) by standard procedures. Critical level of nutrients in index leaf of mature bearing local tall variety of coconut described by Wichmann [7] was subsequently modified by Jacob et. al. [8] to develop rating classes for nutrients in leaf and utilized in the present study [Table-2].

Specific Leaf Nutrient Index (SLNI) was formulated to integrate leaf nutrient ratings for various nutrients in leaf of same AEU into a single index which can be rated and thus, each AEU can be ranked on the basis of SLNI in the order of limitedness of nutrients in leaf. Specific Leaf Nutrient Index (SLNI) was computed as:

Table-1 *Location of the best and common farmer managed coconut gardens, variety and age of palms, best and common farmer yields and yield disparity within agro ecological units (AEUs)*

AEU Code	Name of AEU and District	Block	Panchayat	Variety	Age of palm (years)	Yield (Nuts/palm/year)		Yield disparity (%)
						Best farmer	Common farmer	
3	Onattukara Sandy Plain[R]							
	Alapuzha	Mavelikkara	Thekkekara	WCT	33	250	23	987
11	Northern Laterites[S]							
	Kasargod	Kasargod	Muliyar	WCT	29	208	45	362
8	Southern Laterites[R]							
	Thiruvananthapuram	Nemom	Kalliyur	WCT	42	180	41	339
1	Southern Coastal Plain[S]							
	Thiruvananthapuram	Chirayinkeezh	Kizhuvalam	WCT	35	180	48	275
9	South Central Laterites[H]							
	Ernakulam	Vadavucode	Mazhuvannur	TxD	24	176	27	552
23	Palakkad Eastern Plains[S]							
	Palakkad	Kollengode	Kollengode	WCT	35	175	52	237
2	Northern Coastal Plain[S]							
	Kozhikode	Melady	Thikkodi	WCT	35	170	47	262
12	Southern and Central Foot Hills[H]							
	Ernakulam	Kothamangalam	Kottappady	TxD	34	168	31	442
15	Northern High Hills[S]							
	Kasargod	Manjeshwar	Belur	WCT	41	160	50	220
14	Southern High Hills[A]							
	Idukki	Adimali	Adimali	WCT	14	150	52	188
5	PokkaliLands[A]							
	Ernakulam	Paravur	Chittattukara	WCT	80	144	50	188
13	Northern Foot Hills[S]							
	Palakkad	Mannarkad	Kanjirapuzha	WCT	54	140	49	186
22	Palakkad Central Plains[S]							
	Palakkad	Alathur	Kavassery	WCT	27	130	49	165
10	North Central Laterites[S]							
	Palakkad	Pattambi	Nellaya	WCT	30	110	51	116
4	Kuttanad[H,Y]							
	Kottayam	Vaikom	TV puram	TxD	28	100	38	163
20	Wayanad Central Plateau[Y]							
	Waynad	Kalpetta	Kottathara	WCT	30	86	25	244
6	Kole Lands[Y]							
	Thrissur	Puzhakal	Arimboor	WCT	35	60	44	36
	Mean				36	152	42	292
	SD				14	46	10	217
	SEm				3	11	2	53

[R] - Exceptionally well managed garden under technical guidance and constant supervision of government research institutions namely Central Plantation Crops Research Institute and Kerala Agricultural University, [H] - T x D Hybrid palms which are genetically superior to WCT variety, [A] – Palms beyond the standard productive age range of 20-60 years and [Y] - Palms yielding less than 105 nuts / palm / year where 105 nuts equals 2.5 times or 150 per cent increase in yield over the average common farmer yield of 42 nuts / palm / year, [S] - AEU shortlisted for further investigation into best farmers' management practices.

Table-2 *Rating classes for level of nutrients in leaf[#] of mature bearing local tall varieties of coconut*

Leaf nutrients	Unit	Rating classes		
		Low	Sufficient	High
Nitrogen (N)	%	<1.8	1.8-2.1	>2.1
Phosphorus (P)	%	<0.11	0.11-0.12	>0.12
Potassium (K)	%	<1.2	1.2-1.4	>1.4
Calcium (Ca)	%	<0.35	0.35-0.50	>0.50
Magnesium (Mg)	%	<0.25	0.25-0.35	>0.35
Sulphur (S)	%	<0.15	0.15-0.20	>0.20
Iron (Fe)	ppm	<40	40-115	>115
Manganese (Mn)	ppm	<60	60-120	>120
Zinc (Zn)	ppm	<60	60-72	>72
Copper (Cu)	ppm	<12	12-13	>13
Boron (B)	ppm	<8	8-10	>10

[#] - Fourteenth leaf below the first fully opened leaf designated as index leaf.

$$SLNI = \frac{(1SN_L+2SN_S+3SN_H)}{(SN_L+SN_S+SN_H)}$$

where, SN_L, SN_S and SN_H are number of leaf nutrient ratings for various nutrients in an AEU falling in category of 'low', 'sufficient' and 'high' which are assigned weightage of 1, 2 and 3 respectively. SLNI below 1.67 are rated 'Low', 1.67 to 2.33 'Sufficient' and above 2.33 'High'.Group Leaf Nutrient Index (GLNI) was formulated to integrate leaf nutrient ratings for the same nutrient across various AEUs in a cluster of AEUs into a single index and thus each nutrient in a cluster of AEUs can be ranked in the order of limitedness of nutrients in leaf. Group Leaf Nutrient Index (GLNI) was computed as:

$$GLNI = \frac{(1GN_L + 2GN_S + 3GN_H)}{(GN_L + GN_S + GN_H)}$$

where, GN_L, GN_S and GN_H are number of leaf nutrient ratings for a single nutrient across various AEUs in a cluster of AEUs falling in category of 'low', 'sufficient' and 'high' which are assigned weightage of 1, 2 and 3 respectively. GLNI below 1.67 are rated 'Low', 1.67 to 2.33 'Sufficient' and above 2.33 'High'.

Composite soil samples from base of 4 selected palms in best farmer managed coconut garden were collected from 0 to 40 cm depth at 180 cm away from bole of palm processed and analysed for soil texture, soil reaction, soluble salts, organic carbon and available soil nutrients N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B by standard procedures. Rating for soil reaction as described by DOAC [9] and rating for soluble salts in soil as described by Jones [10] were utilised in the present study. Soil fertility rating for organic carbon and available nutrients in soil as described by ICAR [11] and Olsen and Dean [12] was subsequently modified by Jacob et. al. [8] to develop rating classes for nutrients in soil and utilized in the present study [Table-3].

Table-3 *Rating classes for level of organic carbon and available nutrients in soil*

Organic carbon & Available soil nutrients	Unit	Rating classes		
		Low	Medium	High
Organic Carbon (OC)	%	<0.40	0.40-0.75	>0.75
Nitrogen (N)	Kg/ha	<280	280-560	>560
Phosphorus (Bray-P)	Kg/ha	<16	16-45	>45
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	<0.20	0.20-0.40	>0.40
Boron (B)	Mg/kg	<0.20	0.20-0.40	>0.40

Specific Soil Nutrient Index (SSNI) was formulated to integrate soil nutrient ratings for various nutrients in soil of same AEU into a single index which can be rated and thus, each AEU can be ranked on the basis of SSNI in the order of limitedness of nutrients in soil. Specific Soil Nutrient Index (SSNI) was computed as:

$$SSNI = \frac{(1SN_L+2SN_M+3SN_H)}{(SN_L+SN_M+SN_H)}$$

where, SN_L, SN_M and SN_H are number of soil nutrient ratings for various nutrients in an AEU falling in category of 'low', 'medium' and 'high' which are assigned weightage of 1, 2 and 3 respectively. SSNI below 1.67 are rated 'Low', 1.67 to 2.33 'Medium' and above 2.33 'High'. Group Soil Nutrient Index (GSNI) was formulated to integrate soil nutrient ratings for the same nutrient across various AEUs in a cluster of AEUs into a single index and thus each nutrient in a cluster of AEUs can be ranked in the order of limitedness of nutrients in soil. Group Soil Nutrient Index (GSNI) was computed as:

$$GSNI = \frac{(1GN_L + 2GN_M + 3GN_H)}{(GN_L + GN_M + GN_H)}$$

where, GN_L, GN_M and GN_H are number of soil nutrient ratings for a single nutrient across various AEUs in a cluster of AEUs falling in category of 'low', 'medium' and 'high' which are assigned weightage of 1, 2 and 3 respectively. GSNI below 1.67 are rated 'Low', 1.67 to 2.33 'Medium' and above 2.33 'High'.

Results and Discussion

Production Potential of Coconut

Production potential of coconut alternatively termed as best farmer yield (BFY) ranged from 60 to 120 nuts/palm/year with an average of 152 nuts/palm/year [Table-1]. Highest BFY of 250 nuts/palm/year in Onattukara Sandy Plain is attributed to agricultural practices undertaken by best farmer under technical guidance and supervision of Central Plantation Crops Research Institute. The second highest BFY of 208 nuts/palm/year was in Northern Laterites where best farmer had devised and undertaken management practices independent of government supervision. The third highest BFY of 180 nuts/palm/year was recorded in two AEUs Southern Laterites and Southern Coastal Plain. Best farmer in Southern Laterites had undertaken agricultural practices under technical guidance and supervision of Kerala Agricultural University while best farmer in Southern Coastal Plain had undertaken agricultural practices independent of government supervision. Hence best farmer designed farmer implemented management practices can bear comparison with scientist designed farmer implemented management practices in achieving production potential of coconut in farmers' field. Lowest BFY of 60 nuts/palm/year was recorded in Kole Lands.

Yield Disparity in Coconut

Common farmer yield (CFY) ranged from 23 to 52 nuts/palm/year with an average of 42 nuts/palm/year [Table-1]. Highest CFY of 52 nuts/palm/year was observed in two AEUs Palakkad Eastern Plains and Southern High Hills. Lowest CFY of 23 nuts/palm/year was observed in Onattukara Sandy Plain. Yield disparity (YD) ranged from 36 to 987 % with an average YD of 292 % [Table-1]. Highest YD of 987 % was recorded in Onattukara Sandy Plain which resulted from occurrence of highest BFY and lowest CFY in the same AEU. Since the best farmer in this AEU had implemented management practices under technical guidance and supervision of Central Plantation Crops Research Institute, scientist designed farmer implemented management practices can successfully reduce yield disparity in an AEU. The second and third highest YD of 552 and 442 % recorded in AEU South Central Laterites and AEU Southern and Central Foot Hills respectively were attributed to genetic superiority of T x D hybrids in best farmers' field over locally grown West Coast Tall (WCT) palms. Hence popularisation of high yielding varieties can successfully reduce yield disparity in coconut without amending existing common farmers' management practices. The fourth highest YD of 362 % was observed in Northern Laterites where the best farmer had devised and implemented his own management practices independent of government supervision. Hence best farmer designed farmer implemented management practices can successfully reduce yield disparity in an AEU. Lowest YD of 36 % was recorded in Kole Lands.

Proposed Nutrient Management Plan for Coconut

Level of nutrients in leaf

Specific Leaf Nutrient Index (SLNI) for AEUs ranged from 1.73 to 2.27 for yields 110 to 208 nuts/palm/year. Hence all AEUs were classified into 'sufficient' SLNI group [Table-4]. Group Leaf Nutrient Index (GLNI) for each nutrient across all AEUs in 'sufficient' SLNI group was calculated [Table-8]. Leaf nutrients Zn, Mg, Cu, P and N were rated 'low'; Mn and B 'sufficient'; K, S, Ca and Fe 'high'. Ranking of leaf nutrients in their order of limitedness in 'sufficient' SLNI group of AEUs followed the order Zn>Mg>Cu=P>N>Mn=B>K=S>Ca>Fe with Zn being the most limiting and Fe being the least limiting nutrient in leaf.

Level of nutrients in soil

Yields 180 to 208 nuts/palm/year were achieved in soils having 'sandy loam' texture, 'moderately acid' reaction, 'non saline' electrical conductivity and 'high' organic carbon [Table-5]. These four soil parameters were found to occur in tandem only in soils sustaining yield of 180 to 208 nuts/palm/year exception being AEU 15 Northern High Hills where the best farmer's practise was application of goat manure 0.5 kg/palm at monthly interval and neem cake 0.5 kg/palm at bimonthly interval resulting in high organic carbon content of 2.8 % in soil.

Table-4 *Level of nutrients in leaf, specific leaf nutrient index (SLNI) and their rating*

AEU Code	Yield (Nuts/ Palm/ year)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	B (ppm)	SLNI
13	140	1.79	0.14	1.89	0.80	0.18	0.38	439	192	19	11	10	2.27
		Suff.	High	High	High	Low	High	High	High	Low	Low	Suff.	Suff.
23	175	1.91	0.06	1.46	1.27	0.25	0.21	121	34	24	13	12	2.18
		Suff.	Low	High	High	Suff.	High	High	Low	Low	Suff.	High	Suff.
22	130	1.62	0.18	0.64	1.16	0.25	0.37	192	333	38	11	10	2.09
		Low	High	Low	High	Suff.	High	High	High	Low	Low	Suff.	Suff.
1	180	1.82	0.07	1.43	1.22	0.24	0.13	204	214	23	16	13	2.09
		Suff.	Low	Suff.	High	Low	Low	High	High	Low	High	High	Suff.
2	170	1.96	0.10	1.62	0.13	0.19	0.20	178	122	47	12	12	2.00
		Suff.	Low	High	Low	Low	Suff.	High	High	Low	Suff.	High	Suff.
15	160	1.67	0.10	1.56	1.06	0.04	0.18	282	78	47	4	11	1.91
		Low	Low	High	High	Low	Suff.	High	Suff.	Low	Low	High	Suff.
11	208	1.86	0.06	1.59	0.41	0.07	0.17	247	52	20	10	15	1.82
		Suff.	Low	High	Suff.	Low	Suff.	High	Low	Low	Low	High	Suff.
10	110	1.15	0.08	0.84	0.93	0.17	0.41	148	84	23	8	10	1.73
		Low	Low	Low	High	Low	High	High	Suff.	Low	Low	Suff.	Suff.
Mean		1.72	0.10	1.38	0.87	0.17	0.26	226	139	30	11	12	
SD		0.26	0.04	0.42	0.41	0.08	0.11	100	101	12	4	2	
SEm		0.09	0.01	0.15	0.14	0.03	0.04	35	35	4	1	1	

Suff. – 'Sufficient' rating class.

Table-5 *Soil texture, soil reaction, soluble salt, soil organic carbon and their rating*

AEU Code	Yield (Nuts/palm/year)	Soil texture	Soil reaction	Soluble salt	Organic carbon
			pH	EC (dS/m)	OC (%)
11	208	Sandy loam	5.8	0.19	2.20
			Moderately Acid	Non Saline	High
1	180	Sandy loam	6.1	0.20	0.83
			Moderately Acid	Non Saline	High
23	175	Clay loam	6.3	0.29	0.45
			Moderately Acid	Non Saline	Medium
2	170	Silt loam	6.4	0.25	0.70
			Moderately Acid	Non Saline	Medium
15	160	Sandy loam	6.2	0.12	2.80
			Moderately acid	Non Saline	High
13	140	Sandy loam	5.8	0.03	0.47
			Moderately acid	Non Saline	Medium
22	130	Clay loam	5.4	0.03	0.43
			Strongly Acid	Non Saline	Medium
10	110	Sandy loam	5.6	0.04	0.59
			Moderately Acid	Non Saline	Medium
Mean			5.95	0.14	1.06
SD			0.35	0.10	0.91
SEm			0.12	0.04	0.32

Specific Soil Nutrient Index (SSNI) for AEUs ranged from 2.36 to 2.45 for yields 180 to 208 nuts/palm/year and hence these AEUs were classified into 'high' SSNI group [Table-6]. SSNI for AEUs ranged from 1.82 to 2.27 for yields 110 to 175 nuts/palm/year and hence these AEUs were classified into 'medium' SSNI group [Table-6]. Group Soil Nutrient Index (GSNI) for each nutrient across 'high' and 'medium' SSNI groups were calculated separately [Tables-8]. In 'high' SSNI group of AEUs, soil nutrients N, K and P were rated 'low'; B 'medium'; Ca, Mg, S, Fe, Mn, Zn and Cu 'high'. Ranking of soil nutrients in their order of limitedness in 'high' SSNI group of AEUs followed the order N=K>P>B>Ca=Mg=S=Fe=Mn=Zn=Cu with N being the most limiting and Ca, Mg, S, Fe, Mn, Zn and Cu being the least limiting nutrients in soil. In 'medium' SSNI group of AEUs, soil nutrients Mg, B and N were rated 'low'; K, Ca, S and P 'medium'; Fe, Mn, Zn and Cu 'high'. Ranking of soil nutrients in their order of limitedness in 'medium' SSNI group of AEUs followed the order Mg=B>N>K>Ca=S>P>Fe=Mn=Zn=Cu with Mg being the most limiting and Fe, Mn, Zn and Cu being the least limiting nutrients in soil.

Relationship of nutrients

Correlation coefficients between yield and leaf nutrients, between yield and soil nutrients, between leaf nutrients and soil nutrients and between soil nutrients and soil organic carbon which tested significant are presented in [Table-7]. Yield was positively correlated with N and B in leaf and negatively correlated with S in leaf. Yield was positively correlated with Ca Mg, S and B in soil. Mg in leaf was negatively correlated with S and Zn in soil. B in leaf was positively correlated with Ca, Mg, S and B in soil. S and Zn in soil were positively correlated with organic carbon in soil.

Table-6 *Level of available nutrients in soil, specific soil nutrient index (SSNI) and their rating*

AEU Code	Yield (Nuts/ Palm/ year)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (kg/ha)	Mg (kg/ha)	S (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	B (mg/kg)	SSNI
1	180	276	16	91	575	233	18	76.8	8.1	2.3	0.5	0.3	2.45
		Low	Med.	Low	High	High	High	High	High	High	High	Med.	High
11	208	195	15	118	560	198	60	39.3	19.4	6.5	2.1	0.2	2.36
		Low	Low	Low	High	High	High	High	High	High	High	Med.	High
2	170	360	37	238	273	50	17	76.7	51.6	3.4	3.8	0.1	2.27
		Med.	Med.	Med.	Med.	Low	High	High	High	High	High	Low	Med.
23	175	198	51	214	290	55	21	26.1	38.7	3.5	0.9	0.1	2.27
		Low	High	Med.	Med.	Low	High	High	High	High	High	Low	Med.
15	160	210	70	121	325	45	42	23.9	6.9	8.8	3.6	0.1	2.18
		Low	High	Low	High	Low	High	High	Med.	High	High	Low	Med.
13	140	166	34	203	306	39	8	30.5	14.4	2.9	2.6	0.1	2.09
		Low	Med.	Med.	High	Low	Low	High	High	High	High	Low	Med.
10	110	154	19	351	236	23	3	18.2	42.2	1.9	3.4	0.0	2.00
		Low	Med.	High	Low	Low	Low	High	High	High	High	Low	Med.
22	130	151	22	56	216	19	5	69.4	33.9	4.1	2.7	0.0	1.82
		Low	Med.	Low	Low	Low	Low	High	High	High	High	Low	Med.
Mean		214	33	174	348	83	22	45	27	4.2	2.5	0.10	
SD		71	19	96	140	83	20	25	17	2.3	1.2	0.10	
SEm		25	7	34	49	29	7	9	6	0.8	0.4	0.04	

Med. – 'Medium' rating class.

Table-7 *Correlation co-efficient of significant parameters*

Sl. No.	Parameter	Correlation co-efficient (r)
1	*Yield with leaf nutrients*	
1.1	Yield with B	0.94**
1.2	Yield with S	-0.89**
1.3	Yield with N	0.78*
2	*Yield with soil nutrients*	
2.1	Yield with S	0.79*
2.2	Yield with B	0.78*
2.3	Yield with Ca	0.77*
2.4	Yield with Mg	0.74*
3	*Leaf nutrients with soil nutrients*	
3.1	B with Ca	0.84**
3.2	B with Mg	0.84**
3.3	Mg with Zn	-0.80*
3.4	B with S	0.77*
3.5	B with B	0.76*
3.6	Mg with S	-0.75*
4	*Soil nutrients with soil organic carbon (OC)*	
4.1	Zn with OC	0.92**
4.2	S with OC	0.87**

*Significant 5 % level, **Significant at 1% level

Type of nutrients included in proposed nutrient management plan

Two distinct groups of AEUs 'medium' and 'high' SSNI were identified with yields 110 to 175 and 180 to 208 nuts/palm/year respectively though both these group of AEUs were rated 'sufficient' based on SLNI [Tables-4,6]. When GSNI values for soil nutrients in 'high' SSNI group of AEUs were compared with that of 'medium' SSNI group of AEUs, it was observed that GSNI for N, P and K decreased by 15 to 45 per cent as best farmers' nutrient management practices failed to adequately replenish soil with these nutrients removed by crop [Table-8]. GSNI for Ca, Mg, S and B increased by 39 to 200 per cent as best farmers' nutrient management practices had successfully replenished soil with these nutrients removed by crop. GSNI for Fe, Mn, Zn and Cu remained unchanged by best farmers' nutrient management practices and hence management of these nutrients were ignored in proposed nutrient management plan. Therefore the proposed nutrient management plan focussed on increasing status of nutrients N, P, K, Ca, Mg, S and B in soil while maintaining a favourable soil pH to ensure best availability of nutrients in soil.

Type and quantity of fertilizers included in proposed nutrient management plan

Soil pH 5.8 to 6.1 were recorded in 'high' SSNI group of AEUs applied with 1 to 2 kg lime, 60 to 238 kg organic manures and 1.5 to 2 kg inorganic fertilizers [Tables-5,9]. Lime application was found to counteract inherent soil acidity and acidity generated through decomposition of organic manures and application of acid forming fertilizers. Tisdale et. al. [13] had reported pH range of 6.0 to 6.5 as ideal for maximum P availability in soil. KAU [14] had recommended lime 1 kg/palm/year for coconut. Application of 1 kg burnt lime/palm/year is included in proposed nutrient management plan.

Table-8 *Group leaf nutrient index (GLNI),group soil nutrient index (GSNI) and their rating*

Nutrients& Organic carbon	GLNI	GSNI		
	'Sufficient' SLNI group of AEUs	'Medium' SSNI group of AEUs	'High' SSNI group of AEUs	Percent change
N	1.63	1.17	1.00	-15
	Low	Low	Low	
P	1.50	2.33	1.50	-36
	Low	Med.	Low	
K	2.38	1.83	1.00	-45
	High	Med.	Low	
Ca	2.63	2.00	3.00	50
	High	Med.	High	
Mg	1.25	1.00	3.00	200
	Low	Low	High	
S	2.38	2.00	3.00	50
	High	Med.	High	
Fe	3.00	3.00	3.00	0
	High	High	High	
Mn	2.25	3.00	3.00	0
	Suff.	High	High	
Zn	1.00	3.00	3.00	0
	Low	High	High	
Cu	1.50	3.00	3.00	0
	Low	High	High	
B	2.25	1.00	2.00	100
	Suff.	Low	Med.	
Organiccarbon		2.16	3.00	39
		Med.	High	

AEUs – agro ecological units, Med. - 'medium' rating class, SLNI – specific leaf nutrient index, SSNI – specific soil nutrient index, Suff. – 'sufficient' rating class.

Table-9 *Type and quantity of fertilizers applied in best farmer managed coconut gardens*

Sl. No.	Fertilizer	Quantity (kg/palm/year)							
		'High' SSNI group of AEUs		'Medium' SSNI group of AEUs					
		AEU 11 208 nuts	AEU 1 180 nuts	AEU 23 175 nuts	AEU 2 170 nuts	AEU 15 160 nuts	AEU 13 140 nuts	AEU 22 130 nuts	AEU 10 110 nuts
1	*Soil amendment*								
1.1	Lime	2.0	1	0	0	1.00	0	0	1.00
2	*Inorganic fertilizers#*								
2.1	Urea	0.0	0	1	0	1.00	0	0	0.75
2.2	Factamfos	0.0	1	2	0	0.00	0	0	0.00
2.3	Mixture	0.0	0	0	0	0.00	0	1	0.00
2.4	MussooriePhos	0.0	0	0	0	1.25	0	0	0.00
2.5	Muriate of potash	0.5	1	1	1	1.50	1	1	0.75
2.6	Common salt	1.5	0	0	0	0.00	0	3	0.00
3	*Organic fertilizers*								
3.1	*Bulky organicmanures*								
3.1.1	Green leaf manure	100.0	25	0	0	0.00	0	0	10.00
3.1.2	Farm yard manure	100.0	25	20	6	0.00	0	5	10.00
3.1.3	Coconut biomass	0.0	0	0	10	0.00	0	0	0.00
3.1.4	Compost	0.0	0	0	0	0.00	0	5	0.00
3.1.5	Vermicompost	0.0	0	0	0	0.00	10	0	0.00
3.2	*Concentrated organic manures*								
3.2.1	Neem cake	3.0	0	0	2	3.00	0	0	2.00
3.2.2	Poultry manure	30.0	5	0	0	0.00	0	0	0.00
3.2.3	Goat manure	0.0	5	0	0	6.00	0	0	0.00
3.2.4	Bone meal	0.0	0	0	2	0.00	0	0	0.00
3.2.5	Wood ash	5.0	0	0	0	0.00	0	0	0.00

AEUs – agro ecological units,SSNI – specific soil nutrient index.

- Common salt 39% Na, 61% Cl; Muriate of potash 60% K_2O, 48% Cl; Mussoorie Phos 18% P_2O_5, 38% CaO, 5.6% MgO; Mixture 18% N, 18% P_2O_5, 18% K_2O; Factamfos 20% N, 20% P_2O_5, 13% S; Urea 46% N.

Green leaf manure and farm yard manure 25 to 100 kg each were applied in 'high' SSNI group of AEUs [Table-9]. The 1:1 ratio in quantity of these two organic manures is a unique best farmer management practice. KAU [14] and Adhikary [15] had reported that 1:1 mixture of cow dung and decaying leaves provided with adequate shade and moisture is an ideal substrate for multiplication of earth worms. By enriching farm yard manure with nutrient rich poultry manure and adding to green leaf manure, best farmer had inadvertently done on farm composting, thus provided native earthworms in root zone of coconut with substrate ideal for multiplication. Application of 2:1 and 2.5:1 ratios of green leaf manure and farmyard manure in coconut had been reported by Sadanandan et al. [16] and Karthikeyan [17] respectively. Best farmer had applied 60 to 238 kg organic manures in 'high' SSNI group of AEUs [Table-9]. The adhoc recommendation for coconut palms under organic farming is application of 50 kg farmyard manure or cow dung, 5 kg ash and 200 g *Azospirillum*/palm/year [18]. KAU [14] had recommended application of 50 kg organic manure along with 5 kg neem cake to soil to manage coconut palm infested with coconut mite (*Aceria guerreronis* Keifer). On farm composting with 60 kg organic manures/palm/year comprising of 30 kg each green leaf manure and farm yard manure is included in proposed nutrient management plan.

Application of high quantity of organic manures 238 kg enabled best farmer in

'high' SSNI group of AEUs to achieve yield 208 nuts/palm/year without applying inorganic fertilizer sources for N, P and S [Table-9]. Other best farmer in the same 'high' SSNI group of AEUs supplemented low quantity of 60 kg organic manure with inorganic fertilizer sources for N, P and S through 1 kg Factamfos application to achieve yield 180 nuts/palm/year. Positive correlation existed between S and organic carbon in soil. Hence applied organic manure is the main source of S in soil [Table-7]. Application of high quantity of organic manures to provide S is not quite feasible. Hence, 1 kg Factamfos/palm/year is included in proposed nutrient management plan.

Common salt 1.5 kg and muriate of potash 0.5 kg were applied in the ratio 3:1 in 'high' SSNI group of AEUs [Table-9].Use of common salt and sea water is an ancient and very common practice among coconut growers [19].Coconut possesses starch containing chloroplasts in guard cells [20] which require Cl for stomatal functioning [21,22]. Long term study of salt application to coconut in Philippines found 1.5 kg common salt/palm/year most effective in increasing copra weight and nut yield [23]. KAU [14] had recommended application of 2 kg common salt to coconut pit six month prior to planting to improve soil conditions. KAU [14] had also recommended application of 1.2 kg K_2O/palm/year under good management which translates to application of 2 kg muriate of potash/palm/year. Best farmer had however substituted 75 per cent of recommended quantity of muriate of potash with common salt. Application of 1.5 kg common salt and 0.5 kg muriate of potash/palm/year are included in proposed nutrient management plan.

Muriate of potash 0.5 to 1 kg and organic manures 60 to 238 kg were applied in 'high' SSNI group of AEUs while muriate of potash 0.75 to 1.5 kg and organic manures 9 to 22 kg were applied in 'medium' SSNI group of AEUs [Table-9]. This strategy of reducing high exchangeable K in soil through reduced inorganic K fertilizer application while simultaneously increasing organic manure application enabled best farmer in 'high' SSNI group of AEUs to utilize low quantities of Mg present in soil effectively even without necessitating application of inorganic Mg fertilizers. Tisdale et al. [13] had reported that in low Mg soils, high level of exchangeable K can interfere with Mg uptake by crop. Application of high quantity of organic manures to provide required K is not quite feasible necessitating supplementary inorganic K fertilizer application. Hence, application of inorganic K fertilizer should invariably be accompanied by application of inorganic Mg fertilizer to avoid reduction in yield. Rethinam [24] had recommended application of 0.5 kg magnesium sulphate, 55 kg organic manures and 2 kg muriate of potash to coconut. KAU [14] had recommended application of 0.5 kg magnesium sulphate/palm/year. Application of 0.5 kg magnesium sulphate/palm/year is included in proposed nutrient management plan.

When organic manure 60 to 238 kg were applied in 'high' SSNI group of AEUs, B had 'medium' GSNI whereas when organic manure 9 to 22 kg were applied in 'medium' SSNI group of AEUs, B had 'low' GSNI [Table-9]. This increase in GSNI rating for B from 'low' to 'medium' is attributed to applied organic manure rather than native B bearing minerals in soil successfully replenishing B in soil removed by crop. Positive correlation existing between yield and B in both leaf and soil; and between B in leaf and B in soil, shows importance of adequate soil B to achieve high yield [Table-7]. Since application of high quantity of organic manures to provide required B is not quite feasible, supplementing with inorganic B fertilizer application is necessary to avoid reduction in yield. Rethinam [24] had recommended application of 50 g borax and 55 kg organic manures/palm/year. KAU [14] had recommended application of 20 g borax/palm/year for areca nut palm. Application of 50 g borax/palm/year is included in proposed nutrient management plan.

The general organic manure recommendation for coconut is application of forest leaves, cattle manure, coir dust or coconut shredding at 15 to 25 kg/palm/year along with recommended inorganic fertilizers [14]. In proposed nutrient management plan, on farm composting with 60 kg organic manures consisting of 30 kg each green leaf manure and farm yard manure is suggested and is estimated to contribute 0.29 kg N, 0.06 kg P (0.14 kg P_2O_5), 0.23 kg K (0.28 kg K_2O), 0.34 kg Ca, 0.04 kg Mg and 0.03 kg S/palm/year to soil. The general inorganic fertilizer recommendation for coconut under good management is application of 1 kg dolomite or lime, 0.5 kg N, 0.138 kg P (0.32 kg P_2O_5), 0.996 kg K (1.2 kg K_2O) and 0.5 kg $MgSO_4$ /palm/ year [14]. In proposed nutrient management plan, application of inorganic fertilizers 1 kg burnt lime, 1 kg Factamfos, 0.5 kg muriate of potash, 1.5 kg common salt, 0.5 kg magnesium sulphate and 50 g borax is suggested and is estimated to contribute 0.20 kg N, 0.08 kg P (0.19 kg P_2O_5), 0.25 kg K (0.30 kg K_2O), 0.71 kg Ca, 0.05 kg Mg, 0.20 kg S, 5.5 g B and 1.16 kg Cl/palm/year to soil.

Conclusion

The results of study revealed that agro ecological units (AEUs) of Kerala state having high production potential of coconut were Onattukara Sandy Plain, Northern Laterites, Southern Laterites and Southern Coastal Plains with yields of 250, 208, 180 and 180 nuts/palm/year respectively. AEUs having low production potential were Kole Lands, Wayanad Central Plateau, Kuttanad and North Central Laterites with yields of 60, 86, 100 and 110 nuts/palm/year respectively. Yield disparity between best and common farmer managed coconut gardens in AEUs varied from 36 to 987%. Proposed nutrient management plan based on best farmers' management practices inorder to reduce yield disparity involves application of 1 kg burnt lime, on farm composting with 60 kg organic manures comprising of 30 kg each green leaf manure and farm yard manure, application of 1 kg Factamfos, 0.5 kg muriate of potash, 1.5 kg common salt, 0.5 kg magnesium sulphate and 50 g borax to each palm every year.

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