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Nutrient indexing of benchmark sites of Erode district in Tamil Nadu

SUBRAMANIAN, K.S., POONGOTHAI, S., CHITDESHWARI, T. AND DURAISAMI, V.P.
Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu

Abstract: In order to forecast the emerging micro- and macro-nutrient deficiencies or toxicities in crops and soils resulting from intensive cropping, 15 benchmark sites have been identified in Gobichettipalayam taluk of Erode district in Tamil Nadu, based on the soil physico-chemical properties. The experimental soils were neutral in pH, free from salinity, low in organic carbon, medium in available P & K. The available micronutrient status has shown that the soil available Zn & Cu and Fe & Mn is in the range of deficiency and sufficiency levels, respectively. The soils belong to Irugur (red non-calcareous), Chikkarasampalayam (black calcareous) and Sathyamangalam (black calcareous) series. Two intensive cropping systems such as Rice - Rice and Sugarcane - Sugarcane - Turmeric were chosen for the study. The soil data indicated that both intensive cropping systems have depleted the soil nutrient status heavily. However, as both cropping sequences have been supplied with sufficient quantities of fertilizer inputs carrying macronutrients, soils in the benchmark sites have maintained the inherent soil fertility status. On the other hand, non-addition of micronutrients has caused deficiencies of Zn, Cu and B as indicated by the available nutrient status in both cropping sequences. Plant samples showed sufficiency levels of both macro and micronutrients. The overall data indicated that there is an utmost necessity for application of micronutrients especially Zn, B and Cu to enable to maintain the crop yields in the intensive cropping systems in Erode district. Further, soil nutrient balance has to be maintained by proper substitution of organic and inorganic sources of macronutrients.

Key words: Nutrient Indexing, nutrient balance, macro- and micronutrient status, intensive cropping

Introduction

During the Green Revolution era, the high input and high productive technologies together with high yielding, fertilizer responsive and photo-insensitive varieties have led to the yield revolution in grain crops. With concerted efforts, India had achieved the record production of 209 million tonnes of food grains in 1999-2000 with an all time high buffer stock of 40 million tones. Such a phenomenal increase in food grain production in India has commensurate with a six-fold increase in fertilizer consumption from 0.05 (1950) to 18 million tonnes (2002). However, the yield increase in crops to the addition of fertilizers begins to decline in the past decade as a direct consequence of imbalanced fertilization.

A holistic approach is to be adopted in order to maintain the balance between the crop removal and addition of fertilizers. Balanced fertilizer application is imperative for sustained productivity. In India, the problem is compounded by imbalanced fertilizer use, leading to widening of NPK ratio from 5.9: 2.4: 1 in 1991-92 to 10: 2.9: 1 in 1996-97 as against the optimum ratio of 4 : 2: 1 (Yadav, 2002). Most of Indian soils are deficient but excessive use

Table 1. Soil physico-chemical characteristics and the total nutrient contents in the benchmark sites of Erode district

No.	Crops	pH	EC (dSm^{-1})	$CaCO_3$ (%)	OC (%)	P (%)	K (%)	S (ppm)	Fe (%)	Mn (ppm)	Cu (ppm)	Zn (ppm)	B (ppm)
1	Rice	6.6	0.23	3.25	0.42	0.059	0.35	500	3.69	560	45	110	10.5
2	Rice	7.0	0.26	3.09	0.32	0.068	0.39	625	4.52	515	52	125	12.8
3	Rice	7.7	0.31	3.33	0.26	0.056	0.45	575	4.95	500	58	130	11.6
4	Rice	6.9	0.32	3.98	0.25	0.068	0.52	535	3.95	505	65	110	25.2
5	Rice	6.5	0.25	3.45	0.40	0.054	0.41	500	4.25	510	42	95	30.6
6	Sugarcane	7.4	0.50	1.23	0.40	0.049	0.36	345	4.65	495	45	120	24.9
7	Sugarcane	7.6	0.42	3.11	0.54	0.068	0.32	475	4.23	450	52	1125	20.5
8	Sugarcane	7.5	0.44	3.37	0.56	0.070	0.48	510	4.87	475	60	130	18.9
9	Sugarcane	7.3	0.51	0.90	0.37	0.065	0.44	278	4.75	460	58	110	15.6
10	Sugarcane	7.5	0.48	3.56	0.38	0.058	0.32	555	4.60	510	45	120	25.9
11	Turmeric	7.0	0.36	3.43	0.39	0.069	0.49	545	5.00	485	52	90	20.0
12	Turmeric	6.9	0.93	0.87	0.40	0.075	0.44	265	3.46	525	58	125	18.5
13	Turmeric	7.2	0.62	1.12	0.35	0.080	0.45	270	4.48	548	46	110	22.9
14	Turmeric	7.0	0.45	3.25	0.36	0.075	0.52	490	3.56	516	53	105	15.9
15	Turmeric	7.4	0.53	3.09	0.42	0.064	0.45	460	4.25	489	50	95	32.5
	Mean	7.2	0.44	2.74	0.39	0.060	0.40	433	4.08	471	49	169	19.1

of N alone fails to produce sustainable yields over a long period. Achieving balance between the nutrient requirements of crops and the nutrient reserves in the soils is essential for maintaining high yields and soil fertility, preventing environmental contaminations and sustaining agricultural productions over the long-term. Further, the use of high analysis fertilizers with exclusion of micronutrients in intensive cropping systems has caused deficiencies of micronutrients. It has been reported that the occurrence of micronutrients deficiencies to an extent of 46%, 9%, 5% and 4%, Zn, Fe, Cu, Mn, respectively (Singh and Saha, 1995). Correction of micronutrient disorders is needed for sustainable farm production. In this context, it is appropriate to determine the nutrient balance in the soil to replenish the loss in nutrients suitably. Nutrient balance studies were undertaken in order to assess the emerging trends in nutrient deficiencies or toxicities in agroecosytems.

Materials and Methods

Experimental soil

The study area is P. Vellalapalayam village in Gobichettipalayam, Erode district. The village has a geographical area of 500 ha of which composed of 382 ha irrigated and 101 ha rainfed and the remaining area is being utilized for non-agricultural purposes. During the first phase of the delineation experiment, 200 surface soil samples (50 from rice-rice system and 150 from Sugarcane -Sugarcane-Turmeric System) were analyzed for pH, EC, organic carbon and available macro and micronutrients using standard protocols (Jackson, 1973). The major soil series occurs in the study area is Irugur (red non-calcareous) and

Table 2. Available macro- and micronutrient status of benchmark sites in Erode district

No.	Crops	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	B (ppm)
1	Rice	154	9.0	305	15.3	56.1	17.8	1.69	2.56	0.62
2	Rice	154	8.5	260	20.6	40.8	26.6	2.05	2.48	0.95
3	Rice	160	11.5	185	18.3	48.5	18.5	2.68	3.40	0.84
4	Rice	162	13.0	280	17.5	52.3	25.2	1.84	1.72	0.72
5	Rice	160	10.0	160	14.2	44.9	20.8	1.35	1.59	0.69
6	Sugarcane	174	9.5	210	14.5	30.0	18.1	1.89	0.93	0.52
7	Sugarcane	170	11.0	310	20.6	30.4	18.8	2.98	1.39	0.86
8	Sugarcane	182	12.5	275	19.5	12.3	6.50	1.68	1.22	1.11
9	Sugarcane	180	12.0	260	23.2	11.0	7.00	1.73	1.25	0.75
10	Sugarcane	190	13.5	185	21.5	26.7	6.23	3.49	2.06	1.25
11	Turmeric	195	19.5	230	16.3	27.4	10.5	2.15	1.04	0.95
12	Turmeric	185	10.5	305	20.5	19.5	5.60	2.00	1.65	0.86
13	Turmeric	172	12.0	285	18.6	17.3	4.50	1.65	1.80	0.72
14	Turmeric	170	13.0	270	20.7	24.5	8.50	1.47	1.70	0.62
15	Turmeric	175	11.3	265	18.2	20.7	7.00	1.97	1.45	0.63
	Mean	172	11.8	252	18.6	30.8	13.4	2.04	1.75	0.81

Sathyamangalam series (Typic Ustorthents - red calcareous) that accounts for 75% and the remaining 25% belongs to Chickarasampalayam series (Typic Haplustalf - black calcareous). A total of 40 plant samples comprises of rice (10), sugarcane (15) and turmeric (15) were collected for the assessment of nutritional status. Young leaves of these crops were sampled dried, powdered and digested in diacid mixture. After complete digestion, digested samples were diluted and assessed for macro and micronutrient contents (Subramanian and Charest, 1995).

During the second phase of the experiment, 15 benchmark sites comprising of 5 rice-rice system and 10 sugarcane-sugarcane-turmeric system have been monitored for the nutrient balance for the past five years. The post-harvest soil and plant samples drawn from the crop sequences had been analyzed for macro- and micronutrient contents in order to determine whether intensive cropping systems have caused deficiency or toxicity of nutrients. Yield and nutrient uptake pattern of individual crops in the sequence had been assessed.

Results

Physico-chemical properties of benchmark sites

The 15 benchmark sites were analyzed for its physiochemical characteristics and the data are reported (Tables 1 & 2). The experimental soil texture varies from sandy loam to clay loam. These soils are intensely cultivated with rice-rice or sugarcane-turmeric. Soils have slightly acidic to neutral pH with no salinity hazard. Calcareousness in the soil is at moderate level and a few places showed no

Table 3. Predominant soil profile characteristics and available nutrient status representing 15 benchmark sites

No.	Depth (cm)	pH	EC (dSm⁻¹)	$CaCO_3$ (%)	OC (%)	P (%)	K (%)	S (ppm)	Fe (%)	Mn (ppm)	Cu (ppm)	Zn (ppm)	B (ppm)
Irg	0-12.5	6.5	0.15	1.56	0.36	14.3	175	16	8.60	4.72	2.37	1.10	0.65
	12.5-40	6.8	0.20	1.40	0.28	11.6	196	20	9.96	3.86	2.00	1.17	0.55
	40-78	7.0	0.14	1.95	0.21	12.3	184	22	10.1	4.24	1.86	1.21	0.60
	0-22.5	8.0	0.24	2.75	0.58	15.9	200	20	9.60	5.11	2.86	1.22	0.53
Ckm	22.5-35	8.2	0.32	3.20	0.46	12.8	220	18	10.2	4.86	2.75	1.20	0.61
	35-62.5	8.2	0.33	3.35	0.48	13.3	226	23	12.3	5.00	2.48	1.22	0.60
	62.5-90	8.3	0.37	3.42	0.39	14.2	245	24	11.8	4.96	2.54	1.24	0.59
Sty	0-12.5	8.1	0.30	0.30	0.47	14.3	240	19	9.62	4.86	2.92	1.20	0.60
	12.5-22.5	8.2	0.40	0.40	0.42	13.7	225	22	8.98	5.10	2.70	1.18	0.62

Irg Irugur Series - Red non-calcareous
Ckm Chickarasampalayam Series - Black calcareous
Sty Sathyamangalam Series - Red calcareous

Table 4. Rice yields and nutrient uptake pattern in benchmark sites (Mean of 5 locations)

Season	Grain yield (kg ha⁻¹)	Straw yield (kg ha⁻¹)	Total Nutrient Uptake								
			N (kg ha⁻¹)	P (kg ha⁻¹)	K (kg ha⁻¹)	S (kg ha⁻¹)	Fe (g ha⁻¹)	Mn (g ha⁻¹)	Cu (g ha⁻¹)	Zn (g ha⁻¹)	B (g ha⁻¹)
Kharif01	4300	6450	57.0	27.5	83.4	10.9	2341	742	152	351	105
Rabi 01	4220	6330	47.6	24.5	76.4	10.5	2301	763	150	324	97
Kharif02	4569	6140	51.4	25.4	82.8	11.1	2362	811	154	369	92.8
Rabi 02	4350	6210	58.4	27.8	79.4	11.0	2290	669	136	384	94.8
Cumulative	17439	25130	214.4	105.2	322	43.5	9294	2985	592	1428	389.6

indication of cankar nodules. Organic carbon status is generally low in most of the benchmark sites except in two locations where the organic status. The average total nutrient contents of P, K , S, Fe, Mn, Cu, Zn, and B were 0.06%, 0.5%, 433 ppm, 4.08%, 471 ppm, 49 ppm, 169 ppm and 19 ppm, respectively. The data indicated that the soil is basically rich in K & Fe. The available N, P and K were low, low-medium and medium-high status, respectively. The soil available N was 20-30 kg higher in sugarcane-turmeric system indicating the heavier fertilization than rice-rice system. The experimental locations had sufficient levels of available micronutrients and sulfur status registering exceedingly higher values than the critical levels except in one site where the Zn content was found to be below the critical level. The soil available nutrient status was closely commensurate with the total nutrient pool. The overall nutrient status of the experimental soil has revealed that the benchmark sites have sufficiency levels of Fe, Mn, Cu, S and K. The Zn and P status were low to medium indicating that these nutrients may be limiting factors in the production system.

Profile characteristics

Soil profiles were dug out in three locations encompassing the all 15 benchmark sites and evaluated for their available nutrient status (Table 3). The profile characteristics were clearly distinguishable between red non-calcareous (Irugur series) and black calcareous (Chickarasampalayam series). All the three soil series were free from salinity. The organic status declined progressively with soil depth in all cases. The available nutrient status of different horizons in the three series appears to be similar. However, lime status and EC have conspicuously increased with increasing soil depth in Chickarasampalayam series. Such uniqueness was not observed in red sandy loam soils of Irugur or Sathyamangalam series.

Crop yields and nutrient removal pattern

a. *Rice - Rice System*

In the Rice - Rice Production system, the average grain and straw yields registered were in the range of 4000-4500 and 6000-6500 kg ha^{-1}, respectively (Table 4). The yield potentials observed in the experimental locations were well above the State or National averages of rice crop. The trend of response was similar regardless of seasons or genotypes used by the farmers. The total uptake of nutrients by rice crop was 50-60, 25-30 and 75-80 kg ha^{-1} of N, P and K, respectively. The data clearly indicated that there is a luxuriant consumption of K in comparison to other nutrients. The total S uptake by rice-rice system was 43.5 kg ha^{-1}, indicating the necessity for replenishment through added sources of S. With regard to micronutrient uptake, the removal followed the order of Fe > Mn > Zn > Cu > B. Similar trend of response was reported earlier (Anon, 2003)

b. *Sugarcane -Sugarcane System*

In Sugarcane - Sugarcane system, cane yield, nutrient content and uptake in 10 benchmark sites in the farmers' holdings recorded were reported (Table 5). The cane yield ranged from 160 to 240 tonnes ha^{-1} with a mean average yield of 203 and 177 t ha^{-1} in plant and ratoon crops, respectively. The data indicated that the high productive potentials of benchmark sites that coincided with high fertility status of soils. The nutrient removal from the soil varied from 165-235, 40-52 and 280-330 kg N, P and K, respectively. Micronutrients removal was also several-fold higher than other crops that may tend to indicate that there is need for regular application micronutrients in order match the depletion in the soil native reserve. The cane yield and nutrient removal were slightly lower for the plant crop than the succeeding ratoon crop. The major nutrient content ranged from 1.0 to 2.0% for N, 0.2 to 0.4% for

Table 5. Sugarcane and turmeric yields and nutrient uptake pattern in benchmark sites (Mean of 10 locations)

Year	Cane yield ($t\ ha^{-1}$) or Rhizome yield ($q\ ha^{-1}$)	Total Nutrient Uptake								
		N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	S ($kg\ ha^{-1}$)	Fe ($g\ ha^{-1}$)	Mn ($g\ ha^{-1}$)	Cu ($g\ ha^{-1}$)	Zn ($g\ ha^{-1}$)	B ($g\ ha^{-1}$)
SC (I crop)	203	198.0	55.6	301.0	48.6	12238	2053	680	1271	1679
SC (II crop)	177	155.1	51.5	253.0	42.8	11346	2220	542	1308	1586
Turmeric	5.6	96.9	46.8	214.0	14.4	7106	798	195	477	98.0
Cumulative		461.0	144.0	748.0	107.0	29700	4972	1398	3171	3327

P and 1.11 to 1.30% for K. Whereas the micronutrient content of the cane showed a wide variability. The values ranged from 12.0 to 15.8, 400-520, 19.7 to 26.8 and 4.19 to 10.7 mg kg^{-1}, for Zn, Fe, Mn and Cu, respectively. The crop removal pattern indicated that N is heavily depleted followed by K and P. Similar results were reported by Yadav (2002). With regard to micronutrients, Fe was depleted to a higher extent and order of the removal was Fe > Mn > B > Zn > Cu which reiterates the necessity for addition of micronutrients on a regular basis for yield sustainability.

c. Turmeric System

The turmeric rhizome yield varied from 4.8 to 6.2 t ha^{-1} which nearly double as that of the national average (Table 5). Turmeric rhizomes removed N, P and to the tune of 97, 47 and 215 kg ha^{-1}, respectively, to produce on an average of 5 tonnes of rhizome yield. Potassium uptake was 2.5 times as that of N and 5 times as that of P. The data clearly indicated that the soil K is being heavily depleted by turmeric and proper substitution of K is required to gain maximum yield advantage. Micronutrients have been removed in the pattern of Fe > Mn > Zn > Cu.

Nutrient Balance Studies

Nutrient balance studies were carried out for Rice - Rice system, and Sugarcane - Sugarcane - Turmeric System in order to determine the emerging deficiencies of nutrients (Table 6). The data have shown that in both intensive crop production systems, macronutrients were heavily depleted that has been suitably compensated with addition of inorganic and organic sources of nutrients. Consequently, there was a trend of positive balance maintained for macronutrients in most locations. However, negative balance of all micronutrients was observed in rice-rice cropping system. On the other hand in Sugarcane-Sugarcane - Turmeric system, Fe, Zn and Mn have shown positive balance as these crops are being regularly fertilized with micronutrients in the form of $FeSO_4$ and $ZnSO_4$ in order to alleviate calcium induced deficiencies in soils. The overall data suggest that there is a need for balanced fertilization especially with the inclusion of micronutrients for the maintenance of soil fertility. Similar trend of response has been reported earlier (Singh and Saha, 1995).

Table 6. Nutrient Balance in rice-rice (n= 5) and sugarcane-sugarcane-turmeric system (n = 10)

Nutrients	Cropping Sequence				
	Rice-Rice System		SC-SC Turmeric System		
	2000-01	2001-02	SC 2000	SC 2001	T 2002
N	(+) 143.4	(+)111.2	(+) 127.5	(+) 142.2	(+) 92.4
P	(+) 53.8	(+) 38.4	(+) 25.7	(+) 16.7	(+) 28.6
K	(+) 60.9	(+)37.1	(+) 44.5	(+) 109.6	(+) 45.5
S	(+) 103.4	(+) 95.2	(+) 13.6	(+) 20.4	(+) 14.5
Fe	(-) 5.39	(-)4.91	(+) 22.0	(+) 22.3	(+) 22.8
Mn	(-)1.36	(-)1.41	(+) 0.66	(+) 0.01	(+)1.32
Cu	(-) 0.33	(-) 0.33	(-) 0.61	(-) 0.49	(-) 0.66
Zn	(-) 0.66	(-) 0.89	(+) 0.21	(+)0.14	(+) 0.82
B	(+) 1.05	(-) 0.20	(-)1.5	(-J1.50	(-) 0.09

Conclusions

In two intensive cropping systems namely rice-rice and sugarcane-sugarcane-turmeric, crop yields, uptake and nutrient depletion pattern were studied. The data have clearly indicated that the benchmark sites chosen for the study was a potential area for crop production and the yields were well above the State and National averages. Among the macro nutrients N and K have been removed heavily and with the proper substitution by added fertilizers the soil fertility status is being maintained. On the other hand, non-addition of micronutrients for rice-rice system has caused negative balance in soils. Thus there is an urgent need for inclusion micronutrients in order to maintain the soil fertility and to enable sustainable crop productivity.

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