Volume 1 Issue 1

Journal of
SOIL SCIENCE RESEARCH

Full Paper

JOSSR, 1(1), 2016 [022-031]

Innovative and simplest alternative analytical technology(AAT) for testing soil nutrients

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ABSTRACT

Over the years, different procedures and extracting solutions have been followed by conventional laboratories for testing soil primary, secondary and micronutrients. AAT was developed for testing soil nutrients by following the circular paper chromatography technique and evaluated for its reliability by comparing the results of soil nutrients with conventional analysis by four different laboratories and soil testing kits. Significant differences (20 to 110%) of soil nutrients were recorded among conventional soil testing laboratories. Even after the standardization of procedures and type of equipments used in selected two laboratories were recorded differences upto 20% of soil nutrients. Due to the large variations in the soil nutrients test reports among conventional laboratories the comparison of the soil nutrients was made based on the same (Low-Low, Medium-Medium, High-High), nearby (Low-Medium, Medium-High) and not matching category (Low-High). AAT developed recorded for acceptable level of accuracy (>90 %) for all nutrients such as OC, N, P, K, Ca, Mn, Mg, Cu, pH, Fe and Zn except S (89 %). Increasing the AAT database by over 40% has reduced variations from 30% to 11% between conventional lab and AAT. Therefore, AAT is simple, quick, cost effective, reliable and reproducible for testing soil nutrients.

KEYWORDS

AAT;
Soil test;
Comparison;
Validation;
Conventional.

INTRODUCTION

The term "soil testing" refers to the full range of physical, chemical and biological tests carried out on a submitted sample of soil. Soil testing has a long history in Indian agriculture system, and has contributed significantly to the development of modern scientifically-based production systems. Soil testing becomes indispensable to assure national food security, nutritional security, maintenance of soil health, enhancement of soil fertility and to leave a good heritage for the future generations[5].

In most of the soil testing laboratories in India, only few parameters like pH, electrical conductivity (EC), organic carbon (OC), available nitrogen (N), phosphorous (P), potassium (K) are being analyzed due to the requirement of sophisticated equipments, well- trained manpower and several procedures followed for analysis. The parameters like organic carbon are not often testing, nitrogen are rarely

done and generally derived from organic carbon. The secondary and micronutrients are analyzed rarely due to the need of costliest equipment. There are too many procedures and different equipment are being deployed for analyzing single parameters and hence the cost for testing soil nutrients also high varied from Rs.150/- to Rs.1500/-[10].

There is no simple, cost-effective and reliable technology available to determine the level of organic carbon, humus, nitrogen, phosphorous, potassium and secondary and micronutrients (10) quantitatively in soil so as to provide the farmer the information required for maintaining the health of the soil. Shri AMM MurugappaChettiar Research Centre (MCRC) and IIT-M has jointly developed the "Alternative Analytical Technology (AAT)" for soil nutrient analysis quantitatively by following the principle of Circular paper chromatography technique. It is a good science which has been explained with a very simple experimental design by Ehrenfried E. Pfeiffer[9] for testing the samples qualitatively since 1954. 21,164 soil samples have been processed for the determination of physicochemical properties, circular paper chromatograms, image processing and case-based reasoning. Software for image processing of soil chromatogram so as to know the soil composition, fertilizer recommendation and best suitable crop has been developed.

Several authors have documented variations in soil testing lab results by submitting the same, to several labs for analysis[1-3]. In certain cases, the variations can be explained by use of different extract solutions and procedures[2]. However, variation among labs using the same extract solution and procedure also exists[6]. Some variability is to be expected, but many labs fall outside of generally acceptable standards with high relative standard deviations (RSD, or coefficient of variation) or other measures of variation for certain analyses[3,6]. Therefore this paper deals with the accuracy of different soil testing laboratories, portable soil testing kits and about the importance of simple method of soil testing by Alternative Analytical Technology.

MATERIALS AND METHODS

Collection and processing of soil samples

The soil samples were collected from varied agro climatic zones of Tamilnaduupto one feet depth by following the standard procedure[8]. Collected soil samples of various types and orders were processed and transferred into polythene bag, labeled properly and send to all conventional laboratories for testing soil nutrients.

Physicochemical analysis of soil samples by conventional analysis

Soil were processed for the determination of

TABLE 1 : Standard analytical procedure for testing soil nutrients

S.No	Properties	Method	Reference
1	pH	pH meter 1:2.5 (soil: water)	Jackson (1973) [8]
2	EC	Conductivity meter 1:2.5 (soil: water)	Jackson (1973) [8]
3	Organic Carbon	Wet digestion method	Walkley and Black method (1934) [8]
4	Available Nitrogen	Alkali permanganate method	Subbiah and Asija (1956) [8]
5	Available Phosphorus	$NaHCO_3$ extract-colorimetric method	Olsen *et al.* (1954) [8]
6	Available Potassium	Flame photometer	Jackson (1973) [8]
8	Exchangeable Calcium	Neutral normal ammonium acetate	Jackson (1973) [8]
9	Exchangeable Magnesium	Neutral normal ammonium acetate	Jackson (1973) [8]
10	Exchangeable Sodium	Neutral normal ammonium acetate extract (overnight) using flame photometer	Jackson (1973) [8]
11	Exchangeable Potassium	Neutral normal ammonium acetate extract (overnight) using flame photometer	Jackson (1973) [8]
12	Available Zn, Cu, Fe and Mn	Atomic Absorption Spectrophotometry (DTPA extractants)	Lindsay and Norvell (1978) [4]

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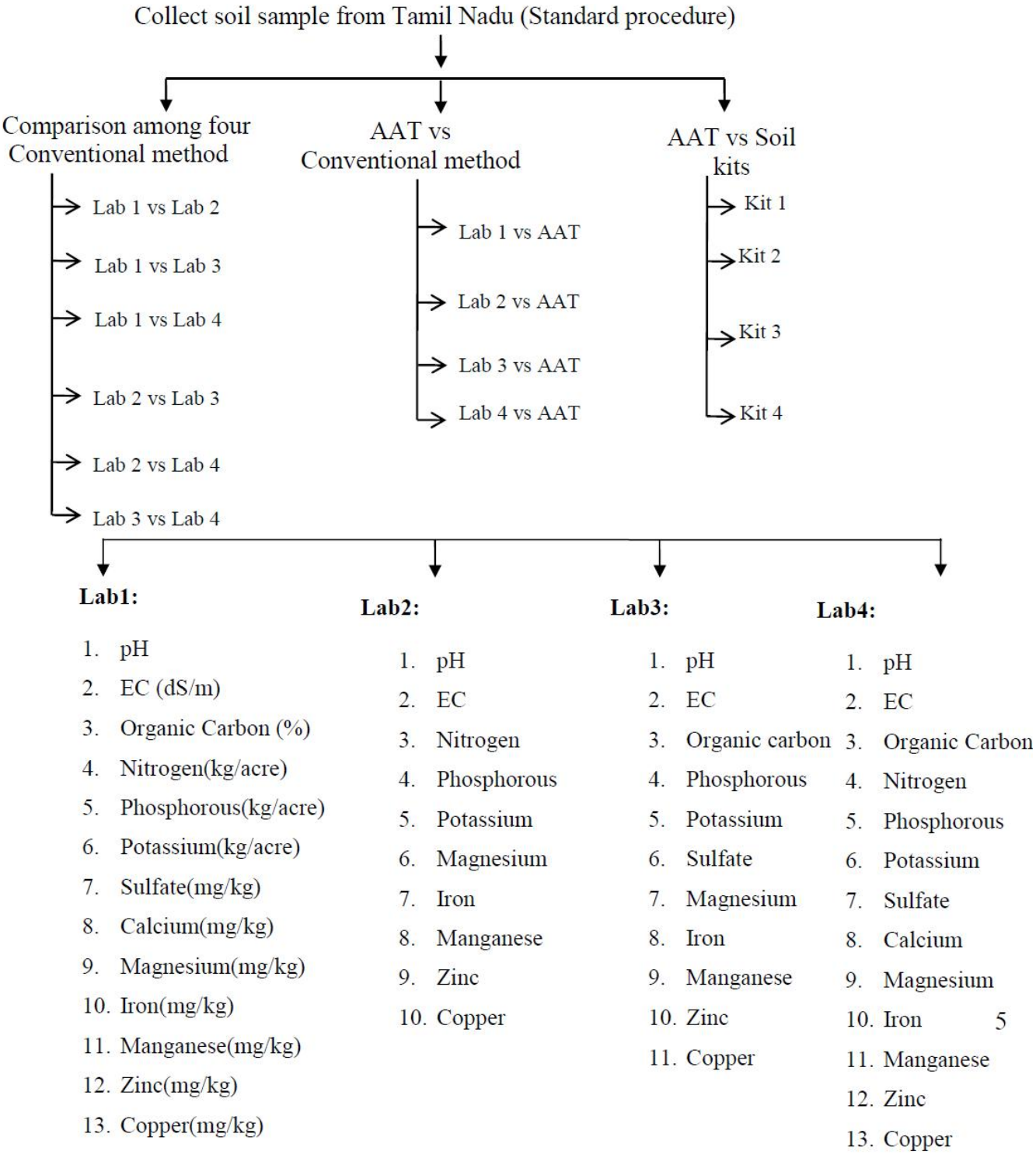
their physicochemical properties such as pH, electrical conductivity, organic carbon, nitrogen, phosphorous, potassium, calcium, magnesium, sulfate, zinc, copper, molybdenum and boron by following the standard analytical procedures and the procedure is detailed below in TABLE 1. For validation the workplan was discussed and designed which was detailed in Flow chart1.

Qualitative analysis of soil samples by circular paper chromatography (CPC)

The collected soils were processed for the determination of nutrients through CPCby following the method as described by Pfeiffer, 1954 and Perumal*et.al*, 2003[9, 10]. The principle of circular



Flow chart 1 : Validation of AAT technology

paper chromatography is in order to separate the humus extracts in the soil or manure by means of capillarity of suitable filter paper. The filter paper is prepared with photo reactive substances which react with the extracted substances. The precipitation of this reaction occurs at various distances from the point of application of the substances to be tested. The distance, the pattern, the color and the shape of the reaction area is significant for an interpretation of the substances contained in the extract.

The test was carried out in a wooden box subdivided into 15 sections, the top of which consists of a glass plate. The size of the box was 3' x 2'x 3' and 15 disc orsamples can be processed in it. Throughout the investigation duplicates were maintained for each experiment.

Dispensed 0.5 ml of 1% $AgNO_3$ in a watch glass and placed the filter paper disc (15 cm diameter) with the wick on the centre of the disc. When the solution reaches the point A removed the wick from the solution and dried the disc in an indirect light. After spreading of silver nitrate up to Point A the same filter paper was inserted with a fresh wick and 0.5 ml of soil or soil input (0.5% NaOH extraction solution) was kept for 1 to 2 hours. When it reached point B (20-25 minutes) removed the wick and dried the filter paper disc under indirect sun light in order to develop zonation, color, pattern and number of spikes.

Quantitative estimation of nutrients in soil by modification in circular paper chromatography

According to the principle of Pfeiffer on circular paper chromatogram, the qualitative determination of soil quality by this method was converted as a quantitative one by implement the advanced ideas. Based on the development of different zone, color, pattern and number of spikes of the images, a database was developed, processed by software for retrieving the results through a system called image processing and case-based reasoning.

Database development

Cases contain knowledge useful for solving the problem. Each Case has two major components: the problem description and solution description. The problem description part is used to retrieve cases from the memory, and the solution description is obtained from the retrieved cases. In the soil analysis problem, the problem description is the chromatogram, represented by the features extracted by image processing techniques. The solution is the soil properties stored with cases for similar chromatogram images.

The case-base containing chromatogram image features which are obtained from the image-processing performed on the chromatogram imagesprepared for each of the soil sample collected. The target features, soil properties, are obtained from the soil analysis unit which currently performs a costly chemical analysis on the collected soil samples to determine the quantity of nutrients.

RESULTS

Collection and processing of soil samples

There are about 50 soil samples were collected from varied agro climatic zones of Tamil Nadu by following the standard procedure[8]. Collected soil samples were transferred into polythene bag, labeled properly and submitted to conventional laboratories.

Physicochemical analysis of soil samples by conventional method

The processed Soils were sent to a conventional laboratory for carrying out physicochemical properties such as pH, Electrical conductivity, organic carbon, Nitrogen, Phosphorus, Potassium, calcium, magnesium, sulphate, zinc, copper, molybdenum and boron for samples by following the standard analytical procedures.

Qualitative determination of nutrients in soil by circular paper chromatography (Pfeiffer 1958)

The collected soils and soil inputs were analyzed for their qualitative differences of nutrients by following the circular paper chromatographic techniques as described by Pfeiffer, 1958. The chromatogram images were interpreted qualitatively as shown in the Figure 1 based on the zone formation like Inner zone indicates presence or lack of mineralization, Middle zone for Organic matter, Outer zone for Humus and Colours, Spikes, Width size of the images.

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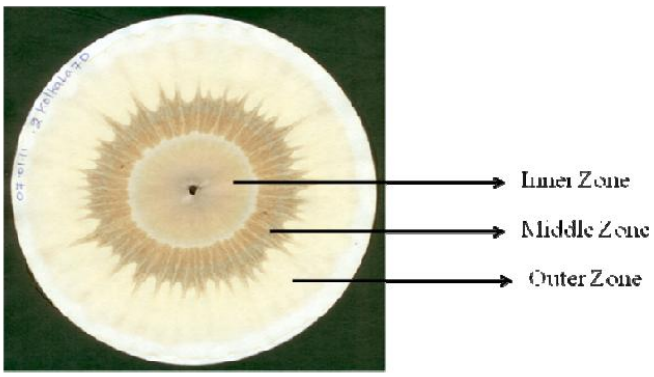


Figure 1 : Chromatogram image

Quantitative determination of nutrients of soil samples by circular paper chromatography (CPC) method

According to the basic principles of CPC by Pfeiffer, the qualitative nutrient finding was modified as quantitative one by implementing modern technologies. The software called soil tool was designed in collaboration with IIT-M for performing the quantitative assessment of soil nutrients and the database consists of physic chemical properties of analyzed by standardized analytical procedure, image features of subsequent chromatogram images and its images(Figure 2a, 2b). The three primary nutrients Viz Nitrogen, Phosphorus, and Potassium (kg/acre), three secondary nutrients Calcium, Magnesium and Sulfate and six micronutrients of sodium, Boron, Copper, Iron, Manganese, Molybdenum and zinc (mg/kg or ppm), all making up a Figure of 13 and organic carbon (%) and humus (kg/acre) in the soil are being critically analyzed through the case based reasoning system.In addition to macro and micro nutrients, pH and EC are also determined through AAT.

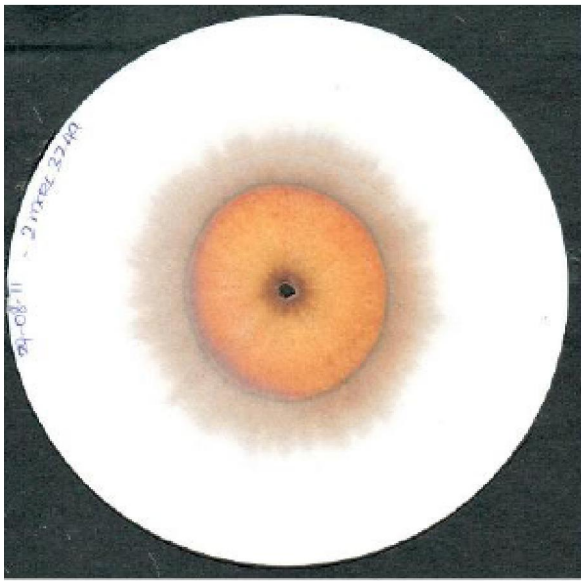
The advantages of this alternative analytical technology on quantification of soil nutrients are simple, reliable, require no sophisticated equipment, quick testing of soil nutrients (18 properties), advice on soil input based on the test report, advice on best suitable crops, should help the farming community and at an affordable cost.

The new technology AAT developed gives acceptable level of accuracy (>90%) for all nutrients compared with conventional analytical methods.

Database and soil tool software developed

The case base in the developed database con-

2a. Nutrient sufficient image



2b. Nutrient deficient image

Figure 2

taining features computed from chromatograms through image processing and mineral properties of soil obtained from soil experts for 21,164 chromatograms[10].

Prediction of soil properties is done by retrieving the best matching cases where the matching is done only on the image features extracted from the chromatogram of the new soil sample. The properties stored in the retrieved cases are used to estimate the soil properties of the given sample.

The validation of AAT technology

The newly developed technology for testing soil nutrients with simple procedure, minimum use of

TABLE 2 : Comparison between conventional soil testing laboratories (before standardization)

Variation	Parameters				
	<10%	10-20%	20-40%	>40%	Total
Organic carbon	1	3	5	41	50
Phosphorous	7	7	6	30	50
Potassium	8	3	19	20	50
Sulfate	0	0	9	41	50
Zinc	14	7	11	18	50
Boron	8	3	7	32	50

TABLE 3 : Comparison between conventional soil testing laboratories (after standardization)

	Parameters				
Variation	<10%	10-15%	15-20%	>20	Total
Organic carbon	13	26	11	0	50
Phosphorous	22	20	5	3	50
Potassium	44	6	0	0	50
Sulfate	23	10	14	3	50
Zinc	47	3	0	0	50
Boron	50	0	0	0	50

TABLE 4 : Comparison of AAT result with conventional laboratory result (12500 data sets)

	Same category	Nearby category	Not matching category
	L/L, M/M,H/H	L/M,M/H	L/H
pH	48	46	6
EC	100		-
OC	28	48	24
P	44	46	10
K	50	50	-
Ca	82	-	18
Mg	98	-	2
Fe	56	22	22
Mn	96	4	-
Zn	30	42	28
Cu	94	6	-
S	30	54	16

Note **same category low-low, Medium-medium, High-high, Nearby category low-medium, Medium-high, Not matching Low-high**

chemicals (only two chemicals) and affordable cost is AAT. This simplified technology was validated by comparing with four different conventional laboratories and four soil testing kits by submitting the same samples as mentioned in the Flow chart1. Hence comparison was made accordingly

1. Among four different conventional laboratories
2. AAT results with conventional laboratory results
3. AAT results with portable soil testing kits

Among four different conventional laboratories

When comparison made among conventional laboratory results (Percentage difference observed between two values), there were large variation from20 to 110% was recorded(TABLE 2).There were many authors recognized and conducted experiments that there are large variations among conventional soil testing laboratories because of using different methodologies, equipment and handling error by technicians.

Therefore, the experiment was conducted again bystandardizing the procedure and calibrated the

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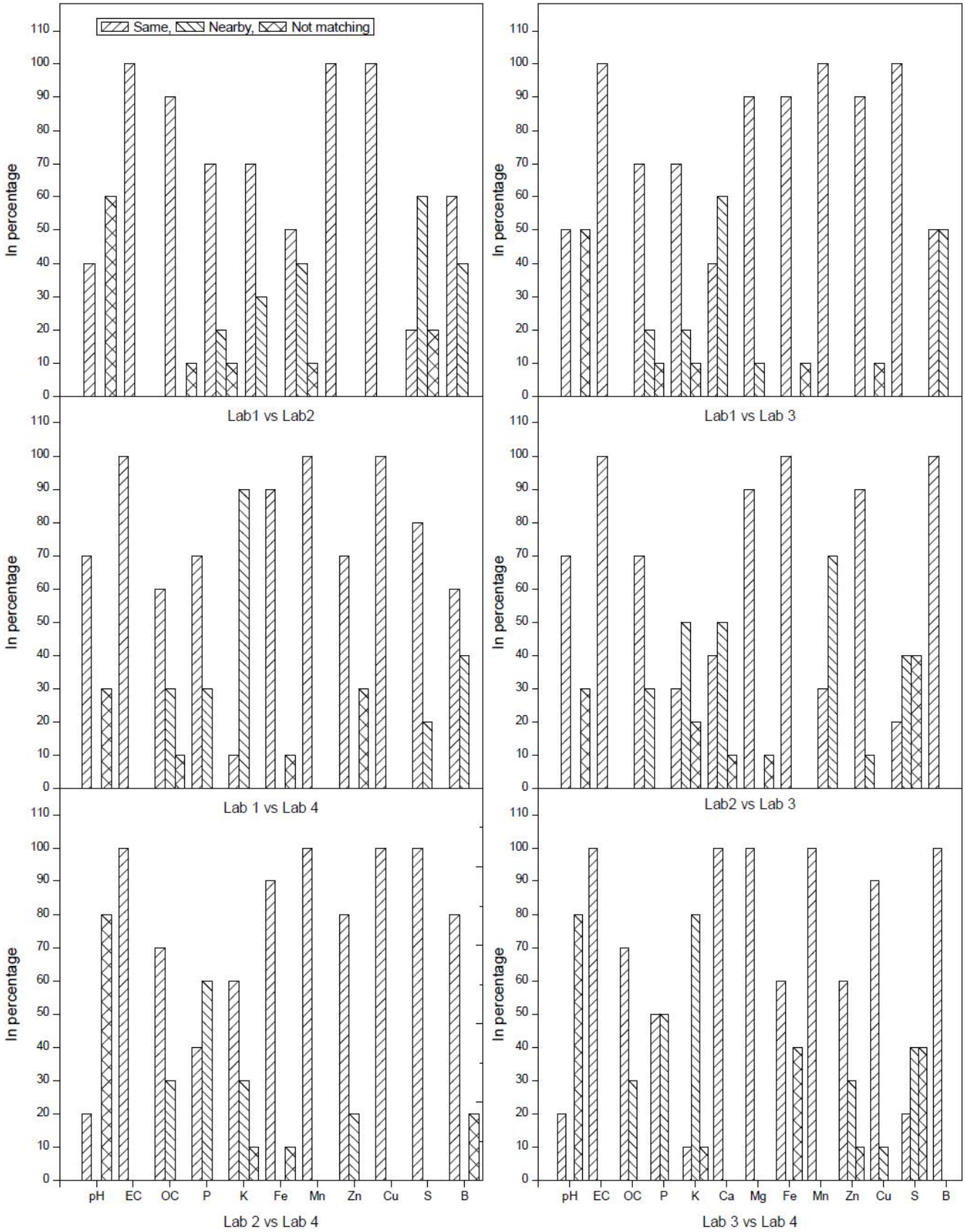
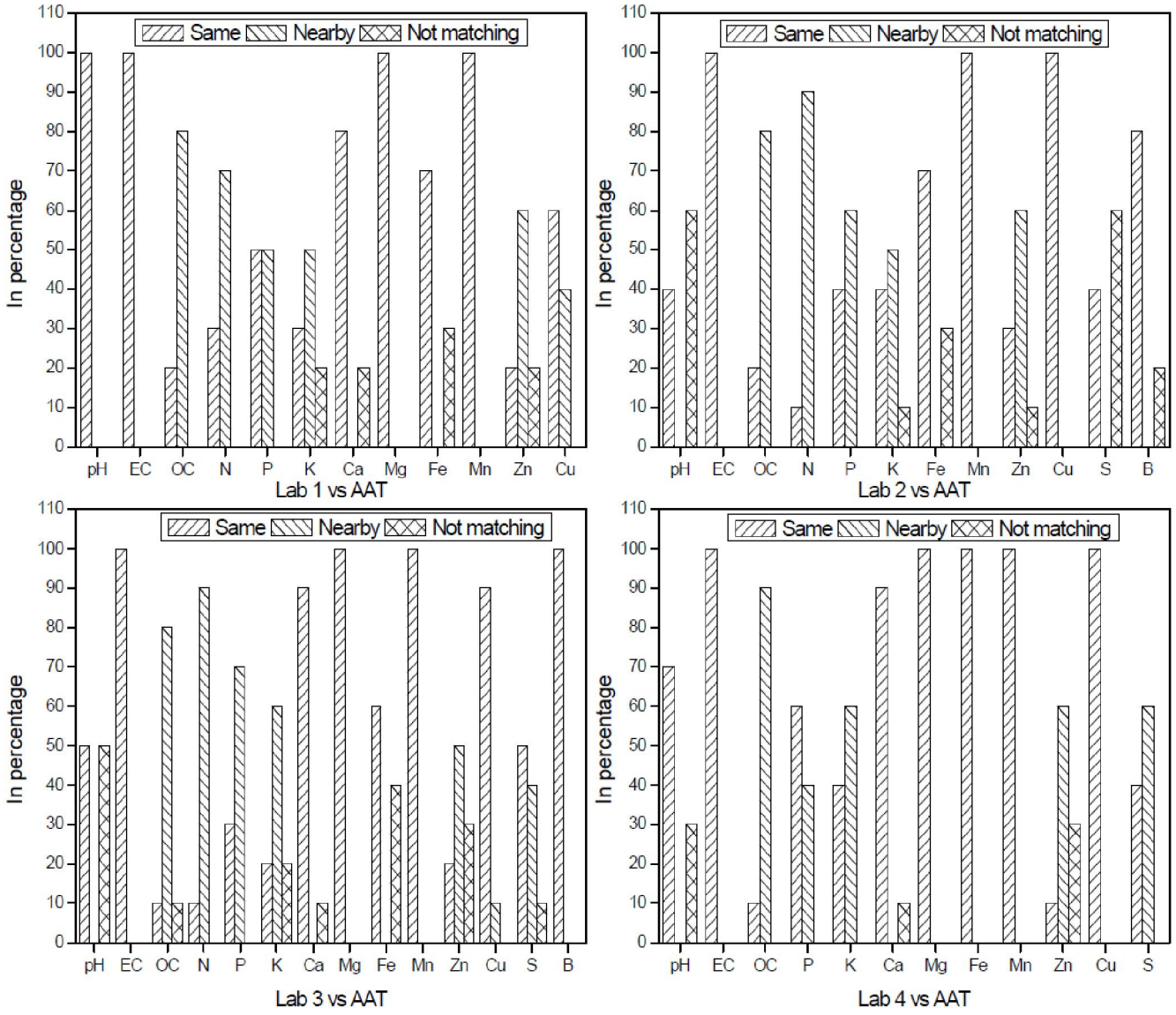


Graph 1 : Comparison among four different soil testing laboratories

equipments between two selected laboratories, even after the standardization there were 20% (5% of er-



Graph 2 : Comparison between AAT and four different soil testing laboratory

ror is precision) of the differences were documented (TABLE 3). Due to the large variations observed among conventional laboratories when comparing the value of one parameter by one laboratory with value of the same parameter of another laboratory (E.g.: 1st lab value of OC 0.7, 2nd lab value of OC 1.5 records 60% percentage differences)to avoid this constrain the comparison was made based onsame category (Low-Low, Medium-Medium,High-High), nearby category (Low-Medium, Medium-High) and not matching category(Low-High) (Graph 1). In this case both the laboratory values have high Organic Carbon content hence both are coming under same category.

AAT with conventional laboratory results

When compare AAT results with conventional soil testing laboratory, out of 12 parameters 100% of EC, K, Mn, Cu 98% Mg, 94% pH,90% P, 84% S, 82% Ca, 78% Fe,76% OC, 72% Zn recordedsame and nearby category.Increasing the database by over 40% has reduced variations from 30% to 11% between conventional lab and AAT. Out of 12 parameters 100% for EC, Ca, Mn, Mg, Cu, 94% for pH, 92% for OC,99% for N and P, 97% for K, 94% for Fe, 93% for Zn, 89% for S recorded same and nearby category.Therefore, increasing the database will further bring down the variations.When compare AAT with other four laboratory results, similarity for major number of parameters comes under same and nearby categories. The major difference was observed in three parameters such as Organic Carbon,

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TABLE 5 : Comparison of AAT result with conventional laboratory result (21,164 data sets)

	Same category	Nearby category	Not matching category
	L/L, M/M,H/H	L/M,M/H	L/H
pH	94	-	6
EC	100	-	-
OC	48	44	8
N	50	49	1
P	60	39	1
K	62	35	3
Ca	100	-	-
Mg	100	-	-
Fe	94	-	6
Mn	100	-	-
Zn	49	44	7
Cu	90	10	-
S	57	32	11

TABLE 6 : Comparison of AAT result with three portable soil testing kits

Sample ID & Kit name	pH	OC (%)	N (kg/acre)	P (kg/acre)	K (kg/acre)
Sample 1- Kit 1	8.00	>0.75	<101	<8	<59
Kit 2	8.50	<0.5	-	0 - 10	>180
Kit 3	6.5 - 7.5	.001 - 0.3	>243	8 to 12	81 - 121
AAT	8.00	1.53	253.20	34.54	105.15
Sample 2 - Kit 1	8.00	>0.75	<101	8 to 16	<59
Kit 2	8.00	<0.5	-	0 - 10	60 - 120
Kit 3	6.5 - 7.5	.001 - 0.3	113 - 162	5 to 8	81 - 121
AAT	8.00	1.04	197.63	23.65	116.70

Potassium and Zinc (Graph 2). But the database increased over 40% (from 12,500 to 21,164) soil samples collected from different regions, has reduced the variation (TABLES 4 and 5).

Comparison between AAT and soil testing kits

There are number of portable on-site soil testing kits available which can give the results qualitatively only such as low, medium and high category with their corresponding value. The four portable kits were purchased and made comparison with them, among the four kits, the fourth kit results interpretation is not comparable with others (provided only low, medium, high and not mentioning the corresponding values).Hence, the randomly selected soil samples were analyzed through three soil testing kits, in which the qualitative result given by the kit results were not match with other kit and also with AAT(TABLE 6).

CONCLUSION

Soil health is one of the most important parameter in the Indian agriculture but still it has not reached at desirable levels with farmers despite huge efforts by Government and Private sector. There are 609 soil testing laboratories in India and its analyzing capacity is 78,32,000 samples. But only 87% of samples are being analyzed currently with available laboratories which covering only 68,39,000 samples. The number of agricultural holdings in India is 11, 99, 30,000 but it will take about 15 years to analyze samples from all holdings at full capacity. Soil testing of all holdings to estimate native fertility levels to ensure appropriate recommendation is important. But we do not have the infrastructure to accomplish the task.

The reason for not coping up of soil testing is farmer's low awareness about soil health and the

importance of soil test based balanced fertilizer application. The results not reaching in time and not properly explained to them. The Soil science is playing a main role in agricultural field for past several decades. Since there is no simple, cost effective technology for testing soil nutrients. The simple technology called AAT is an interesting technology to national and international audience and this was first introduced by the German scientist Pfeiffer and many of the foreign European countries like Sweden, Switzerland, and China, Egypt are following this qualitative test still for testing the manure, soil and food products. The experimental design and analysis of the data for this paper are given adequately.

Therefore the Alternative analytical technology (AAT) for testing soil nutrients is significantly improves the understanding of soil processes by means of simplifying the soil testing procedures which helps to reduce the cost and time and it will ensure the complete analysis and complete coverage of soil testing in future.

ACKNOWLEDGEMENT

We gratefully acknowledge for financial support from Technology Systems Development Programme, Department of Science and Technology.It is our pleasure to thank all the collaborators of this project Indian Institute of Technology (M), E.I.D. Parry India ltd, and Coromandel International ltd.

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