Creation of GIS thematic maps of available Zinc status in major Barnyard millet growing blocks of Madurai district of Tamil Nadu

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Abstract

Zinc plays a critical role in cereal crop production and the present study was conducted in major barnyard millet growing blocks of Madurai district with a vision to assess the soil available zinc status. One hundred fifty-two soil samples were collected from barnyard millet cultivated villages belonging to three major blocks viz., Thirumangalam, Usilampatti, and Kalligudi of Madurai district. The soil available Zinc status in these three blocks ranged from 0.09 mg kg^{-1} to 2.78 mg kg^{-1} with a mean value of 0.77 mg kg^{-1}. The results of the study showed 90 per cent of soil samples were low in available zinc status, 7 per cent in medium status and 3 per cent of soil samples under high status. Among the three blocks, kallikudi block soil samples registered high percentage of low available zinc status (93 per cent) which was followed by Usilampatti (92 percent). Simple correlation and multiple regression analysis was also done to determine the most influencing soil properties on available zinc, which in turn aids to ascertain the degree of relationship between them.

Keywords: Available zinc, GIS approach, soil, barnyard millet

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Introduction

Small millets are gaining importance because of their nutritional value and adaptability to drought and varied soil conditions. Realizing the nutraceutical values of small millets, they are now considered as “nutri-cereals”. For those living in dry land areas, millets are a good source of nutrition. They have other dietary qualities that can aid in preventing anemia, celiac disease, and diabetes. They are particularly rich in iron, calcium, and zinc. Barnyard millet (*Echinochloa* species) is an ancient millet crop grown in warm and temperate regions of the world and widely cultivated in Asia, particularly India, China, Japan, and Korea. In terms of area (0.146 m ha^{-1}) and production (0.147 mt), India is the world's largest producer of barnyard millet, with an average productivity of 1034 kg/ha during the last 3 years [1]. In India, it is an important dry land small millet crop. It is cultivated over a wide array of environmental conditions and poor soils and is mainly confined to tribal belts of Odissa, Maharashtra, Gujarat, Madhya Pradesh, Tamil Nadu and Bihar besides hills of Uttar Pradesh [2].

Barnyard millet is primarily cultivated for human consumption, though it is also used as a livestock feed. Among many cultivated and wild species of barnyard millet, two of the most popular species are *Echinochloa frumentacea* (Indian barnyard millet) and *Echinochloa esculenta* (Japanese barnyard millet) [3]. According to [4], zinc is an essential nutrient for the completion of growth and development of plants. In several significant metabolic pathways in plants, zinc plays a significant role as a structural component or regulatory cofactor of a variety of enzymes. Additionally, zinc serves as an enzyme's metal activator and catalyses the manufacture of indole acetic acid, which ultimately boosts crop yield. By knowing the importance of zinc in barnyard millet production, the present study was undertaken to assess the available zinc status in barnyard millet growing areas through Global Positioning System (GPS). Results obtained from this study will help to develop zinc recommendation for barnyard millet growing under zinc deficient areas which will alleviate the zinc deficiency and enhance the barnyard millet yield.

Material and Methods

Study Area

Madurai district is situated in the south of Tamil Nadu state. It is bounded on the north by the districts of Dindigul, Thiruchirapalli and on the East by Sivagangai and on the west by Theni and south by Vridhunagar. It is located between 9°30 and 10°30 north latitude and 77°00 and 78°30 east latitude. The mean annual rainfall for the Madurai district is about 857.6 mm with the mean annual temperature of 28.8 °C. Madurai district comprises of seven taluks and thirteen blocks. Among them, three are major barnyard millet growing blocks *viz.,* Thirumangalam, Usilampatti and Kalligudi. The thematic map for the study area is given in the Figure 1.

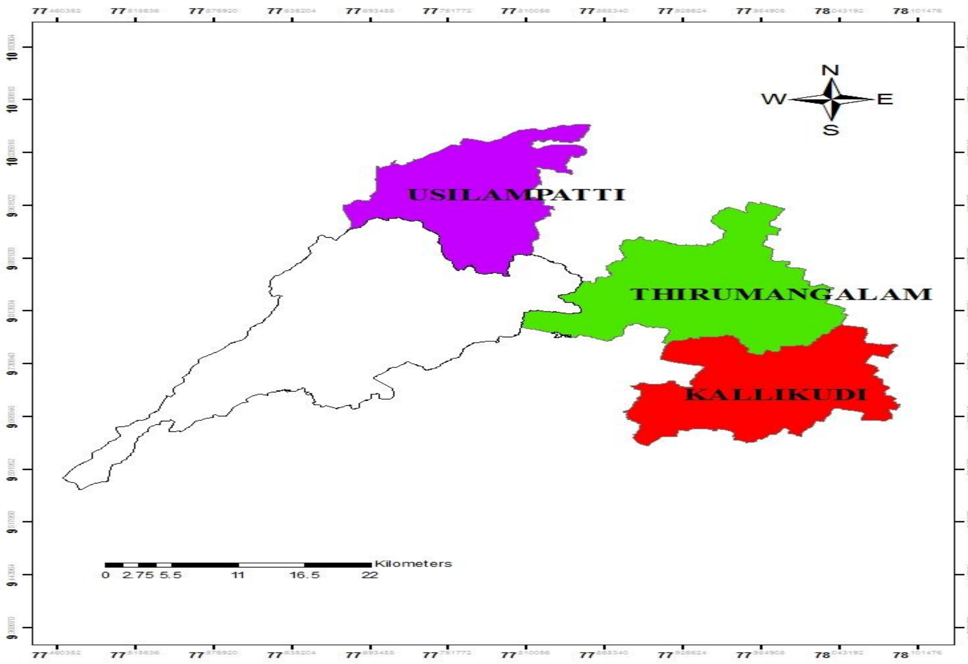

Fig 1: Study area Map

Collection and analysis of soil samples

A total of 152 samples were collected from predominantly barnyard millet growing villages in majority barnyard millet cultivated blocks of Madurai district (Thirumangalam, Usilampatti and Kalligudi). Fifty soil samples were collected from selected villages of each block by using GPS – Garmin Etrex Vista HCX model. The collected soil samples were air-dried, ground and sieved through 2-mm sieve (0.2 mm sieve for organic carbon), labeled and stored. The samples processed were analyzed for chemical parameters *viz.*, pH and $CaCO_3$ [5].

Available DTPA zinc

The available DTPA zinc of soils was estimated by using ((i). Diethylene Triamine Penta Acetic Acid (0.005M) (ii). $CaCl_2$ $2H_2O$ (0.01M) and (iii) Triethanolamine (TEA) 0.1M Solution. The DTPA extractant solution is prepared by dissolving 13.1ml of TEA, 1.967 of AR grade DTPA and 1.47g of $CaCl_2$ in 100 ml glass distilled water. The content was allowed for some times so that the DTPA will dissolve and then diluted to about 900 ml. The pH of the solution was adjusted to7.3 ± 0.05 with 1:1 HCL by stirring and the volume made upto 1litre.) 0.005 M DTPA extract through Atomic absorption spectrophotometer. Based on the analytical results, these soils were categorized into below critical level (< 1.20 mg kg^{-1}), medium (1.20 – 1.80 mg kg^{-1}) and above critical level (>1.80 mg kg^{-1}) outlined by [6].

Statistical and Spatial Analysis

The Pearson correlation coefficients were estimated for all possible paired combinations of the response variables to generate a correlation coefficient matrix. These statistical parameters were calculated with SPSS 16.0® software (SPSS Inc., Chicago, III., USA). The simple correlation was arrived at as per the method. In this research, the base map constructed on study area, the GPS points and values obtained through chemical analysis were coupled together. The study area boundary was digitized using Arc GIS-10.1 environment and polygonized. The geo coordinates of sampling sites were fed into the Arc GIS environment and finally transformed in to thematic map by spatial interpolation technique of kriging [7].

Results and Discussion

Soil physico-chemical properties

The overall mean of pH in soils of barnyard millet growing blocks in Madurai district ranged from 5.61 to 8.96 with a mean of 7.60 representing that the soils are acidic to strongly alkaline in reaction (Table.1). The interpretation on pH of soils indicated that 38 per cent was moderate alkaline (8.0 – 8.5), 24 per cent was neutral, 13 per cent samples was moderately to slightly acidic (5.5 – 6.5), 14 per cent samples was slightly alkaline (7.5 – 8.0) and 9 per cent samples was strongly alkaline (8.5 – 9.0). Relatively higher pH of the soils might be owing to the higher degree of base saturation in these soils. Similar findings were reported by [8] [9].

The electrical conductivity (EC) of the soil indicated the concentration of total soluble salts in soil. The data on EC of the soil samples (Table 1) showed all the samples were found to be non-saline. The non-saline nature of the soil samples might be due to proper management practices and inherent properties of soil as already reported by [10].

Organic Carbon

The organic carbon content in the soils ranged between 1.00 to 9.8 g kg^{-1} with a mean value of 4.91 g kg^{-1}signifying that the soils of barnyard millet growing areas were low in organic carbon status (Table.1). About 51 per cent of the soil samples were under low carbon content (<5 g kg^{-1}), 33 per cent samples indicated medium carbon content (5 – 7.5 g kg^{-1}) and remaining 14 per cent of the soil samples under high carbon content (> 7.5 g kg^{-1}). The low organic carbon content might be primarily due to high temperature leading to higher rate of organic matter decomposition which further leads to extreme high oxidation conditions [11] and also due to little or no organic matter additions [12].

Free $CaCO_3$

All the soil samples from the major barnyard millet growing blocks were found to the non-calcareous in nature (Table 1) as per the rating limit suggested by [13]. The non-calcareous nature of the soils might be due to the presence of powdery form of $CaCO_3$ [14].

Table 1: Range and mean values of the soil properties in major barnyard millet growing blocks of different blocks of Madurai district

S.No.	Name of the blocks	Soil properties			
		pH	EC (dSm^{-1})	Organic C (g kg^{-1})	Free $CaCO_3$ (%)
1.	Thirumangalam	6.70 – 8.77 (7.90)	0.06 – 0.67 (0.23)	1.00 – 9.7 (5.06)	0.84 – 3.25 (1.30)
2.	Usilampatti	5.61 – 8.23 (7.08)	0.02 – 0.43 (0.10)	1.00 – 9.8 (5.30)	0.12 - 2.37 (1.12)
3.	Kallikudi	6.32 – 8.96 (7.95)	0.05 – 0.71 (0.14)	1.2 – 9.2 (4.20)	0.25 – 3.95 (1.43)
Over all mean		5.61 – 8.96 (7.60)	0.02 – 0.71 (0.15)	1.00 – 9.8 (4.91)	0.12 – 3.95 (1.27)

( ) values in parentheses indicate the mean values

Available DTPA – Zn

The critical level of available zinc in soil is 1.2 mg kg^{-1}. The range and mean values of soil zinc for major barnyard millet growing blocks are listed in Table 2. Available zinc content varied from 0.09 to 1.99, 0.21 to 2.78, 0.20 to 1.79 mg kg^{-1} with corresponding mean values of 0.85, 0.80 and 0.66 mg kg^{-1} in Thirumangalam, Usilampatti and Kalligudi blocks respectively. The results represented that Thirumangalam, Usilampatti and Kalligudi block soil samples registered low zinc status in 84, 92, and 93 per cent of the area respectively. Among the three blocks, the overall sample mean values of Thirumangalam (0.85 mg kg^{-1}), Usilampatti (0.80 mg kg^{-1}) and Kallikudi (0.66 mg kg^{-1}) represented below critical levels of available zinc. By combining the three major barnyard millet growing blocks the overall results registered 90, 7 and 3 per cent of the area as low, medium and high respectively in term of zinc content. Low zinc fertility status in these soils might be due to the infrequent application of zinc to the barnyard millet by the farmer who cultivate it as a major crop. The low availability of Zn content in the investigated soil samples might be due to the low Organic carbon in the soil samples tested. The results of the present investigation are in conformity with [15][16][17] who envisaged that when the soils are low in organic matter and not supplemented by mineral fertilization they are prone to zinc deficiency.

Table 2: Range and mean values of soil available Zinc in major barnyard millet growing blocks of different blocks of Madurai district

S.No.	Block name	DTPA-Zn (mg kg^{-1})			Fertility rating
		Min.	Max.	Mean	
1.	Thirumangalam	**0.09**	**1.99**	**0.85**	**Low**
2.	Usilampatti	**0.21**	**2.78**	**0.80**	**Low**
3.	Kallikudi	**0.20**	**1.79**	**0.66**	**Low**
Overall mean		**0.09**	**2.78**	**0.77**	**Low**

Zinc and its relationship with soil Characteristics

To measure the influence of soil properties *viz.*, pH, EC, OC and free $CaCO_3$ on available zinc, the correlation studies have been worked out in Table 3. The correlation studies revealed that the zinc content in the soil was negatively correlated with the soil parameters viz. pH (r = -0.759**), EC (r = -0.314*), OC (r = -0.639**) and free $CaCO_3$ (r = -0.735**) which reinforces the relevance of our finding inferring that low availability of Zn content in the investigated soils might be due to the low organic content of the soil in these blocks.

Table 3: Simple correlation on available Zinc with soil properties in major barnyard millet growing soils of Madurai district

Correlations					
	pH	**EC**	**OC**	**$CaCO_3$**	**Zn**
pH	1				
EC	0.397**	1			
OC	0.512**	0.406**	1		
$CaCO_3$	0.789**	0.384**	0.514**	1	
Zn	-0.759**	-0.314**	-0.639**	-0.735**	1
**. Correlation is significant at the 0.01 level (2-tailed).					

Thematic maps

The thematic maps were generated at village level in three major barnyard millet growing blocks of Madurai district to depict the available Zinc status in those areas based on soil analytical results. The available soil zinc status in three major barnyard millet growing blocks of Madurai district is given in the Figure. 2. The obtained results might help in sorting out the zinc deficient area from those of zinc sufficient areas which will aid in devising the management practices to improve the available zinc content in soils.

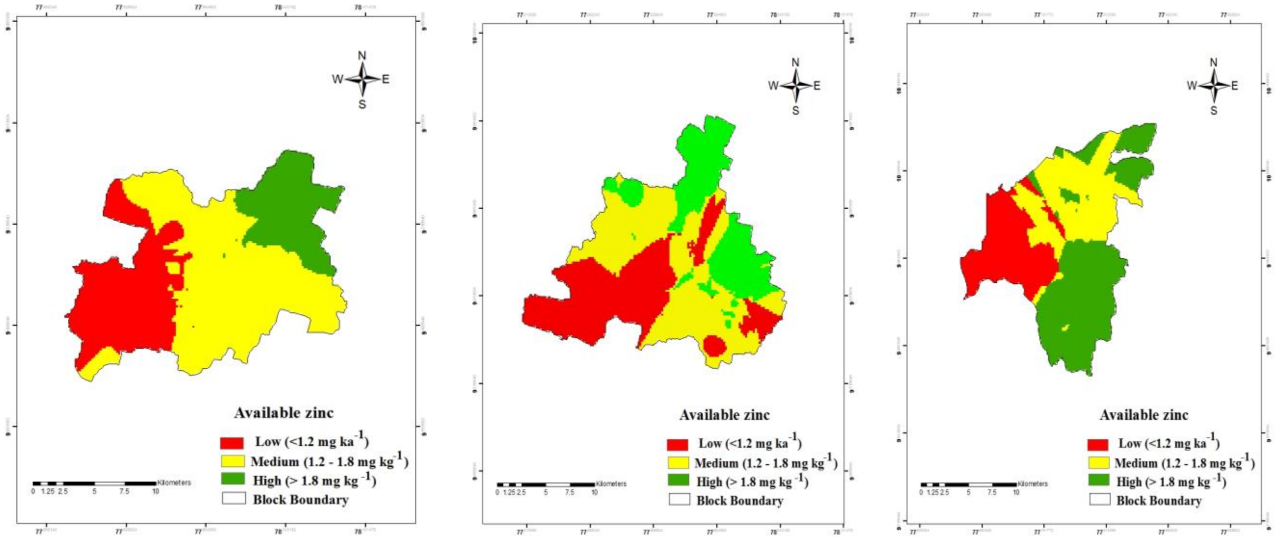

Fig 2: Available zinc status of major barnyard millet growing areas in Kallikudi, Thirumangalam, Usilampatti block of Madurai district

Conclusion

The present investigation revealed that the barnyard millet growing soils from the study area were moderately alkaline in nature which is reflected in low available zinc content. It was further observed that 93 per cent, 84 per cent and 92 per cent of soil samples had low available zinc content in Kallikudi, Thirumangalam and Usilampatti respectively. Geospatial distribution of Zinc in the soils of study area will be highly useful for guiding the barnyard millet growing farmers to decide the optimum amount of zinc to be applied for getting higher yield and economic returns. The georeferenced sampling sites can be revisited with the aid of GPS which will further help in monitoring the soil fertility changes that takes place in the agricultural field over long run. It would be valuable soil resource information to the researchers, farmers, and State Department of Agriculture and extension workers. The status of available zinc in soil depicts that it may be deficient in future due to over exploitation of nutrients by intensive farming. Hence care should be taken to maintain the levels of available Zn in the soil to overcome the increasing deficiency in the near future. The use of organic manures or inorganic micronutrient fertilizers can be implemented to increase the micronutrient availability.

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