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Analysis of Soil Micronutrients Status Using Mathematical Modeling

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Abstract- In this paper the status of various micronutrients like Zink, Copper, Iron and Manganese in soil were calculated using mathematical modeling. Also the steady state level of these micronutrients in soil was estimated for the long term application of particular fertilizer practices. We also discussed the behavior of soil micronutrients level under the application of different level of phosphorus fertilizer and manure applications.

Keywords- Mathematical model, Micronutrient, Phosphorus.

I. INTRODUCTION

Soil plays major role in building of agricultural system and ecosystem. Presence of the micronutrients in soil is very important for maintaining soil health. Although plants require a very small amount of micronutrients in comparison to other essential nutrients or macronutrients yet they are of great importance. Their shortage may cease plants growth. Crop production may also be declined in soil deficient in micronutrient. Removing of nutrients by harvesting, massive P fertilization practices and substances used for maintaining soil acidity may cause of insolubility of micronutrient in soil [1]. Shortage of soil micronutrients may even cause plant's death though other essential nutrients are fully available. So it is required to pay attention in this direction also. Soil variability assessment and maintenance of soil health is of great importance for environmental predictions, ecological modeling and natural resource management [2, 3]. Knowledge of the status of micronutrients in the soil helps producer to choose suitable fertilization practices also to avoid deficiency of micronutrients and toxicity problems. The basic fundamental for selection of any method for soil analysis is that, a positive correlation should exist between concentration of nutrient calculated using method and the nutrient amount which plants intake [4].

Various methods are available for the assessment of micronutrient in soil. Several chemical extractants can be used for determination of soil micronutrients like Cu, Zn, Fe etc. Selection of an extractant depends on specific conditions of agriculture field. In lab, determination of plant-available micronutrients can be done by some common chemical extractants with dilute HCl acid solutions, Mehlich-1, DTPA and EDTA [5, 6].

Electronics kit and simulation techniques are also useful in the assessment of available soil macronutrients (N-P-K) and micronutrients (Zn, Cu and Fe). It is possible by placing kit in deep soil and with GPRS and GPS and the results are being analyzed without any lab testing. PROTEUS software was used for simulation [7].

Geostatistical techniques are also useful in estimation of content of micronutrients. It was found that exponential and spherical semivariograms models are best fitted on the basis of the higher values of R^2 and lower values of RSS in an experiment conducted at various places in Sevapuri (Uttar Pradesh), in which Zn, B and Fe micronutrients were estimated. Using these models a spatial distribution map was prepared which shows the soil status of Zn and B boron are moderate whereas soil status of Fe is strong [8].

In the present paper, we used model [9] for the assessment of soil micronutrient status. Section 1 contains introduction, in section 2 we present mathematical model and its solution, section 3 shows validation of model, result and discussion are contained in section 4 and section 5 presents conclusion and future scope of work.

II. MODEL

In our previous work we developed a model to predict level of different macronutrient under the influence of a particular fertilizer practices. That model can be used for the estimation of status of few micronutrients.

Major equations of model are

$$m_{(i,1)} = m_{(i-1,2)} - u_{(i,1)} + e_1 \quad (1)$$
$$m_{(i,2)} = m_{(i,1)} - u_{(i,2)} + e_2 \quad (2)$$

for two crops in a year.

Where $m_{(i,1)}$ and $m_{(i,2)}$ are soil micronutrient status after first and second crop while $u_{(i,1)}$ and $u_{(i,2)}$ are micronutrient uptake amount by first and second crop respectively in i^{th} year. e_1 and e_2 are the built-up level of micronutrient due to the factor other than considered in basic equations for first and second crop respectively.

$$u_{(i,1)} = \gamma_1 m_{(i-1,2)} + c_1 \quad (3)$$
$$u_{(i,2)} = \gamma_2 m_{(i,1)} + c_2 \quad (4)$$

Where γ_1 and γ_2 are average soil micronutrient efficiency $(0 \le \gamma \le 1)$, c_1 and c_2 are the uptake of micronutrient from unaccounted sources for first and second crop respectively $(c \ge 0)$.
Solutions of above equations are

$$m_{(i,1)} = (1-\gamma_1)^i (1-\gamma_2)^i m_{(0,1)} + \left[\frac{1-(1-\gamma_1)^i (1-\gamma_2)^i}{1-(1-\gamma_1)(1-\gamma_2)}\right]\{(1-\gamma_1)(e_2-c_2)+(e_1-c_1)\} \quad (9)$$

$$m_{(i,2)} = (1-\gamma_1)^i (1-\gamma_2)^i m_{(0,2)} + \left[\frac{1-(1-\gamma_1)^i (1-\gamma_2)^i}{1-(1-\gamma_1)(1-\gamma_2)}\right]\{(1-\gamma_2)(e_1-c_1)+(e_2-c_2)\} \quad (11)$$

In long run, micronutrient level in soil can be calculated by taking limit i→∞, we get

$$m_1 = \left[\frac{(1-\gamma_1)(e_2-c_2)+(e_1-c_1)}{1-(1-\gamma_1)(1-\gamma_2)}\right] \quad (10)$$

$$m_2 = \left[\frac{(1-\gamma_2)(e_1-c_1)+(e_2-c_2)}{1-(1-\gamma_1)(1-\gamma_2)}\right] \quad (12)$$

where m_1 and m_2 denote the steady state level of micronutrient in soil after first and second crop respectively.

III. VALIDITATION OF DATA

Using reliability indices (k_g based on geometric approach and k_s defined by using statistical techniques) given by Leggett [10], we can verify that predicted soil micronutrient status agrees with observed one. k_g and k_s are defined as follows-

$$k_g = \frac{1+\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1-y_i/x_i}{1+y_i/x_i}\right]^2}}{1-\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1-y_i/x_i}{1+y_i/x_i}\right]^2}}$$

and $$k_s = \exp\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\log\frac{y_i}{x_i}\right)^2}$$

where x_i and y_i denote the predicted value and observed value respectively. If $k_g = k_s = 1$, then model is perfect.
We applied above mentioned model on available date of an experiment conducted at RCA, Udaipur entitled "Integrated Nutrient Management in blackgram (Phaseolus mungo L.)"[11].

Experimented soil is of clay loam in texture. Here we consider following five treatments,

i. P-0
ii. P-20
iii. P-30
iv. P-40
v. FYM

Average soil micronutrient efficiency parameter was given by $\gamma = \frac{\sum u_i^0 m_{i-1}^0}{\sum (m_{i-1}^0)^2}$

where u_i^0 and m_{i-1}^0 are uptake and soil available micronutrient of control plots respectively.

IV. RESULT AND DISCUSSION

Estimated value of e, γ and c for various micronutrients (Zn, Cu, Mn and Fe) presented in tables 1 to 4 respectively under various fertilization practices.

The values of e_1 and e_2 in the table 1 to 4 show that there is build up of all micronutrients about all fertilization practices. In table 2, e_1 for Cu shows build up is almost same for different P-fertilization while about FYM it were measured 25% extra in comparison of control P. From table 1 and 3, it was found that build up increased slightly as the dose of P fertilizers increased. For FYM the buildup of Zn is soil were measured 14% extra and Mn were 35% extra than control P whereas table 4 shows a slight reduction of Fe about different P fertilizer practices in comparison of P control. Tables 1 to 4 show significant increment in build up all micronutrients about P fertilizer.

e_2 shown in all table 1 to 4 that there is significant increment in buildup of all micronutrients after wheat crop for P fertilization.

Table 1: Estimation of γ , e and c for micronutrient Zn for different crops in sequence

	BLACKGRAM			WHEAT		
	γ_1	e_1	c_1	γ_2	e_2	c_2
P-0	0.16	196.14	0.89	0.30	152.06	30.89
P-20	0.18	204.35	2.11	0.34	174.26	27.21
P-30	0.20	212.32	2.67	0.37	194.23	26.28
P-40	0.22	213.43	4.26	0.40	209.07	28.65
FYM 5	0.21	225.50	1.48	0.36	190.22	29.25

Table 2: Estimation of γ , *e* and *c* for micronutrient Cu for different crops in sequence

	BLACKGRAM			WHEAT		
	γ_1	e_1	c_1	γ_2	e_2	c_2
P-0	0.06	32.03	3.69	0.22	96.28	25.00
P-20	0.07	31.02	4.32	0.25	111.79	24.73
P-30	0.07	31.05	5.17	0.28	126.62	25.66
P-40	0.08	31.54	6.18	0.30	135.43	24.99
FYM 5	0.08	40.97	4.79	0.27	123.13	26.01

Table 3: Estimation of γ , *e* and *c* for micronutrient Mn for different crops in sequence

	BLACKGRAM			WHEAT		
	γ_1	e_1	c_1	γ_2	e_2	c_2
P-0	0.03	280.97	0.53	0.07	57.38	36.72
P-20	0.03	311.70	1.10	0.07	60.65	30.78
P-30	0.03	319.59	2.50	0.08	69.37	25.52
P-40	0.04	325.70	4.09	0.09	75.24	25.90
FYM 5	0.04	368.72	0.97	0.08	67.47	29.11

Table 4: Estimation of γ , *e* and *c* for micronutrient Fe for different crops in sequence

	BLACKGRAM			WHEAT		
	γ_1	e_1	c_1	γ_2	e_2	c_2
P-0	0.15	955.18	0.07	0.40	1004.99	97.41
P-20	0.17	916.94	1.36	0.47	1144.57	97.45
P-30	0.18	942.77	1.81	0.52	1255.18	89.59
P-40	0.20	948.81	7.60	0.56	1341.12	85.94
FYM 5	0.19	781.34	3.65	0.48	1221.38	96.71

For blackgram, significant increment in soil micronutrient efficiency for Zn and Fe as were observed as the amount of added P fertilizer were increased in soil, but soil micronutrient efficiency for Mn and Cu remain same for different application of P fertilizer whereas for wheat, soil micronutrient efficiency for Mn remains same while soil micronutrient efficiency Zn, Cu and Fe were measured increasing about different P fertilization.

For wheat, amount of micronutrients due to unaccounted sources i.e *c* were measured less about different P fertilizer application in comparison of control P application whereas it was observed higher about FYM application whereas for blackgram, it was measured higher about different P fertilization practices in comparison of control P application.

Table 5: Predicted steady state of soil Zn, Cu, Mn, Fe status (gm ha^{-1}) for different crops in sequence

	BLACKGRAM				WHEAT			
	Zn	Cu	Mn	Fe	Zn	Cu	Mn	Fe
P-0	719.45	358.77	3316.20	3537.17	625.60	350.69	3120.62	3023.22
P-20	697.70	360.57	3309.66	3212.21	607.73	357.35	3095.58	2752.60
P-30	688.64	362.34	3166.91	3140.61	600.68	362.67	2951.91	2687.68
P-40	656.25	358.33	3028.28	3023.11	572.66	361.26	2813.13	2591.24
FYM5	708.15	391.80	3664.84	2932.65	615.07	385.07	3420.96	2645.67

Comparison between predicted and observed soil status for different micronutrients Zn, Cu, Mn and Fe are presented in following tables from 6 to 9 respectively.

Table 6: Observed and predicted value of soil Zn status (gm ha^{-1}) after harvesting different crops in sequence year wise

	BLACKGRAM				WHEAT			
	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004
P-0	655.00	619.90	637.50	660.97	610.75	642.87	598.75	635.75
P-20	645.00	618.19	627.50	654.90	598.25	627.79	589.75	618.53
P-30	640.00	619.17	625.00	653.83	594.50	620.38	588.25	610.55
P-40	632.50	606.67	610.00	633.11	587.25	600.58	572.50	585.69
FYM5	657.50	628.33	635.00	667.86	611.00	636.49	597.25	625.88

Table 7: Observed and predicted value of soil Cu status (gm ha^{-1}) after harvesting different crops in sequence year wise

	BLACKGRAM				WHEAT			
	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004
P-0	595.00	550.47	590.00	499.44	570.00	529.97	545.25	482.25
P-20	592.50	542.27	577.50	487.83	566.25	522.04	533.75	472.70
P-30	587.50	534.99	570.00	478.03	561.25	513.32	527.25	463.61
P-40	572.50	527.15	565.00	467.25	546.50	497.55	520.25	449.19
FYM5	600.00	546.69	585.00	496.93	574.75	530.95	541.75	484.09

Table 8: Observed and predicted value of soil Mn status (gm ha^{-1}) after harvesting different crops in sequence year wise

	BLACKGRAM				WHEAT			
	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004
P-0	3032.50	2676.28	2877.50	2734.27	2885.00	3040.49	2752.50	3047.75
P-20	3025.00	2684.02	2912.50	2748.21	2872.50	3032.24	2747.50	3038.74
P-30	2937.50	2675.42	2917.50	2731.20	2790.00	2939.14	2725.00	2940.58
P-40	2932.50	2663.17	2910.00	2707.67	2782.50	2917.95	2700.00	2905.18
FYM5	3060.00	2728.71	3002.50	2832.09	2912.50	3099.86	2817.50	3135.32

Table 9: Observed and predicted value of soil Fe status (gm ha^{-1}) after harvesting different crops in sequence year wise

	BLACKGRAM				WHEAT			
	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004
P-0	2537.50	2854.09	2827.50	3188.23	2462.50	2775.10	2767.50	2896.47
P-20	2517.50	2763.82	2662.50	3013.58	2442.50	2648.46	2602.50	2706.47
P-30	2505.00	2767.52	2642.50	2992.62	2430.00	2615.22	2580.00	2658.94
P-40	2457.50	2730.84	2595.00	2919.33	2382.50	2543.75	2537.50	2574.38
FYM5	2607.50	2624.47	2765.00	2803.02	2532.50	2629.61	2702.50	2638.91

Reliability indices k_g and k_s are given in following tables 10 and 11 for different micronutrient and both crops. It shows that observed and predicted data agree closely.

Table10. Reliability index k_g of Zn, Cu, Mn and Fe for the proposed model

Micronutrients	CROP	Treatment				
		P-0	P-20	P-30	P-40	FYM
Zn	BLACKGRAM	1.0477	1.0435	1.0403	1.0403	1.0492
	WHEAT	1.0574	1.0491	1.0408	1.0229	1.0449
Cu	BLACKGRAM	1.1388	1.1442	1.1513	1.1576	1.1420
	WHEAT	1.1062	1.1089	1.1171	1.1311	1.1022
Mn	BLACKGRAM	1.1001	1.0985	1.0842	1.0888	1.0952
	WHEAT	1.0844	1.0842	1.0674	1.0637	1.0914
Fe	BLACKGRAM	1.1262	1.1159	1.1193	1.1183	1.0107
	WHEAT	1.0946	1.0656	1.0577	1.0486	1.0320

Table11. Reliability index k_s of Zn, Cu, Mn and Fe for the proposed model

Micronutrients	CROP	Treatment				
		P-0	P-20	P-30	P-40	FYM
Zn	BLACKGRAM	1.0477	1.0435	1.0403	1.0403	1.0492
	WHEAT	1.0574	1.0491	1.0408	1.0229	1.0449
Cu	BLACKGRAM	1.1389	1.1443	1.1514	1.1577	1.1420
	WHEAT	1.1062	1.1089	1.1171	1.1312	1.1022
Mn	BLACKGRAM	1.1002	1.0986	1.0843	1.0888	1.0952
	WHEAT	1.0844	1.0842	1.0674	1.0637	1.0914
Fe	BLACKGRAM	1.1262	1.1159	1.1193	1.1183	1.0107
	WHEAT	1.0946	1.0657	1.0578	1.0486	1.0320

V. CONCLUSION AND FUTURE SCOPE

Above used mathematical model works good for the assessment of soil micronutrients status affected with different dose of P fertilizers and FYM. It also helps in prediction of steady state of different micronutrient level in soil under long term application of P fertilizers and FYM. The work can be extended for the assessment of nutrients status for different fertilizer practices.

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