Asian Journal of Chemistry Vol. 20, No. 3 (2008), 2320-2326

Functional Relationships Between Fertility and Some Soil Parameters

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The importance of empirical and theoretical model derivation in agriculture has been increased due to presence of overwhelming data obtained from researches in soil science and extensive usage of computer in Agriculture. Mathematical definition of fertility is significantly related to research of ecological fertility, usage of maximum parameter values, management and prediction of fertility. The derivation of mathematical models and their application after execution of field and laboratory studies are important steps in comprehending soil fertility. Some agroecological, agrophysical and agrochemical characteristics of soils that constitute conceptual soil model are taken into account in the field and laboratory studies in order to obtain fertility model for irrigated gray-meadow soils. These parameters were determined, evaluated and studied based on the field experiments. The relationships between the parameters and productivity of cotton were found out and static models were derived by using the least square methods. The correlation coefficients (average R = 0.90) of these models with multiple parameters came out to be statistically significant. The extreme points of function were calculated in order to obtain maximum level of the product cultivation in theoretical way. The evaluation of fertility level of experimental soils by these empirical models seems to be possible as well.

Key Words: Fertility, Empiric model, Soil, Parameter.

INTRODUCTION

Nowadays, the derivation of models aiming for fertility management by gathering, systematizing and using the soil parameters in order to improve and preserve fertility is one of the main objectives of agriculture. In the period of automatic management systems, derivation of fertility models for different types of soil has become one of the important factors, which has big importance in constitution of a model set.

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The details of values obtained from experiments conducted in different agricultural fields enables derivation of models and determination of their application possibility. In soil science, the issues of a) derivation and evaluation of models that express natural procedures and their interaction between each other in the best way, b) conducting quantitative modification in soil based on external factors and values of soil characteristics, c) determination of external factors that yields optimum values of soil parameters, need to be solved, as it is done in scientific analysis methods. Model derivation is realized by taking general theoretical and experimental data into account. This data help to determine the main factors effecting research procedure.

In the field of soil science, the main initiative for model derivation is identifying their application possibility in agriculture, which helps to set direction of research, determination of model limitations, selection of needed parameters, model details and its accuracy in the model studies beforehand. The models for physical, physical-chemical, biological procedures are still derived separately. However, soil is a natural system, which is originated as a result of mutual relationships between external and internal factors. One of those processes non taking into account may result in loss of important soil parameters in general and in relatively lower quality of research. Therefore, the important soil factors that possess more effect on fertility have to be taken into consideration during the research. As in other science branches, model derivation has to be realized in parallel with all other research methods in order to exploit systematic approach method in agricultural researches. The application of model in computer is one of the main phases in modeling complicated systems along with determination of the main parameters of system and mutual relationships among them, derivation of model that expresses variation and the status of parameters[1]. The details of the data have been gathered in soil science due to fast development of agriculture science. The consolidation of these data and model derivation based on them is possible due to computer usage. In recent years, different computer programmes ("Diana", "Mediana", *etc.*) have been used in deriving different fertility models, which can be used in predicting variation of soil characteristics, effect of such variation on fertility, soil management and observation of plant's biological development, based on experimental and theoretical data[2-6].

The main objective of this study to determine the important parameters based on their fertility level (low, medium, high) that express different soil characteristics of gray-meadow soils planted with cotton, deriving some linear and non-linear fertility models and obtaining the appropriate values for their parameters in order to maintain maximum level of productivity based on these models.

EXPERIMENTAL

The research was conducted on gray-meadow soils planted with cotton in Imishli and Agjabedi regions of Azerbaijan Republic. These soils can be found in areas covered with dry subtropical climate and natural plants consisted of Artemisia meyerina. In both regions, 15 and 12 experiments were conducted consecutively during time period of 3 years (1991-1994). These experiments were taken as a base for the evaluation. It was found out that these soils contain very low level of nutriment that can be consumed by humus and plant. The average amount of exchangeable cations (Ca + Mg + Na) is 27.24 meq/100 g in 0.50 cm of soil layer, which is considered to be satisfactory. It was observed that the soils contain carbonate (based on CO_2) and have satisfactory level of gypsum ($CaSO_4 \cdot 2H_2O$) on their surface. The soil pH is alkali and the soil texture varies from clay to loam (Table-1).

TABLE-1
SOME PHYSICAL AND CHEMICAL PROPERTIES OF THE EXPERIMENTAL SOILS

Depth (cm)	OM (%)	pH	Exchangeable Na + Ca + Mg meq/100 g	Water soluble NH_3-N (mg/kg)	Absorption of phosphorus (mg/kg)	Exch. K (mg/kg)	< 0.01 mm particle amount %	CO_2 (%)	$CaSO_4 \cdot 2H_2O$ (%)
0-25	1.73	8.1	27.46	3.76	12.61	281.33	50.79	3.55	0.99
25-50	1.04	8.1	27.02	2.25	8.46	244.67	47.13	3.46	1.24
50-75	0.60	8.3	25.97	-	-	-	56.00	4.10	1.76
75-100	0.42	8.3	24.99	-	-	-	56.85	4.57	1.47
100-150	0.36	8.2	24.28	-	-	-	56.82	4.22	1.49

OM = Organic matter.

The values of soil parameters belonging to time period of 3 years, which correspond with fertility level (low, medium and high) appropriate for cotton, were systematized and averaged. Then functional relationships were obtained by using Minitab-32 software programme. The maximum fertility and values of its corresponding parameters were obtained by calculating extreme points of the function.

RESULTS AND DISCUSSION

Derivation of mathematical models to be used for studying processes in soil by systematic approach method and predicting these processes have become one of the main issues. Generally, these models can be classified under two main groups *i.e.*, theoretical and empirical. Empirical models are derived after determination of parameters belonging to system as a result of experiment. In agricultural researches, these models are derived based on results obtained from experiments executed on arable field and are generally called experimental models. These models can be expressed as linear or non-linear based depending on research purpose.

Determination of main soil parameters that expresses different soil characteristics (agro ecological, physical, chemical, *etc.*) and finding out relationships among them have a great importance in estimation of soil fertility. Therefore, correlation coefficients among i) agroecological parameters which are total amount of sun radiation, average temperature, sum of temperatures above 10 °C, average annual rainfall and sum of average irrigation water; ii) agrophysical parameters which are bulk density, particle density, porosity, water stable particles > 0.25 mm, amount of clay, particles smaller than 0.001 mm, field capacity; iii) agrochemical properties which are water soluable NH_4-N, plant available NH_4 + NO_3-N, water soluble phosphorus, labile phosphorus, exchangeable cations (Ca, Mg, Na), organic matter (OM) and pH, iv) water-salt regime properties which are amount of salt, salt concentration of ground water, depth of round water; v) amount of N, P, K fertilizer were determined. The parameters used in the correlation model were sum of temperatures above 10 °C-(X_1), exchangeable Na-(X_2), amount of water resistant particles (> 0.25 mm)-(X_3), OM-(X_4), amount of salt-(X_5), exchangeable Ca-(X_6), NO_3-N-(X_7), amount of phosphorus fertilizer-(X_8), sum of annual rainfall and irrigation water- (X_9). The double correlation coefficients between parameters and fertility were calculated (Table-2). In Table-2, there are higher correlations (R = 0.849-0.958) among the following fertility parameters; X_3-X_2; X_4-X_2; X_4-X_3; X_6-X_3; X_6-X_4 and X_7-X_6. There are also negative correlations (R = -0.748, -0.953) among the following parameters: X_5-X_2; X_5-X_3; X_5-X_4; X_6-X_5; X_7-X_5; X_8-X_1; X_9-X_1. There has also been determined that correlation coefficients among the other parameters were relatively low. Soil-climate conditions of the area, level of soil improvement, agrotechnological methods, biological characteristics of cotton are the main factors causing in difference of relationships among fertility parameters.

Multiple regression coefficients between fertility and soil parameters were determined and the results are aligned in descending way in Table-3. In Table-3, there are higher relationships between fertility and some soil parameters in most cases. Some multiple regression models were expressed as following:

$$Y = -243.00 + 87.100X_1 + 6.344X_4 - 0.041X_6 + 0.141X_9$$

$$Y = 29.10 + 28.610X_4 - 12.390X_5 + 4.891X_7$$

$$Y = 277.00 + 24.250X_5 - 0.399X_6 + 0.583X_7 - 3.163X_8$$

$$Y = 16.40 + 2.970X_2 - 0.321X_3 - 40.690X_5$$

$$Y = -200.0 + 65.470X_4 + 0.125X_9$$

TABLE-2
CORRELATION COEFFICIENTS BETWEEN FERTILITY AND PARAMETERS EXPRESSING DIFFERENT CHARACTERISTICS OF SOIL

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Y	1.000	0.851	0.840	0.770	0.863	-0.992	0.790	0.768	0.866	0.796
X_1		1.000	0.308	0.513	0.449	0.559	0.454	-0.664	-0.858	-0.453
X_2			1.000	0.849	0.890	-0.820	0.727	0.366	-0.308	0.405
X_3				1.000	0.958	-0.796	0.906	0.257	-0.513	-0.592
X_4					1.000	-0.847	0.952	0.888	-0.449	-0.415
X_5						1.000	-0.755	-0.748	-0.395	-0.664
X_6							1.000	0.352	-0.454	-0.572
X_7								1.000	0.664	-0.420
X_8									1.000	-0.512
X_9										1.000

TABLE-3
REGRESSION COEFFICIENTS OF PARAMETERS BELONGING TO REGRESSION AND THEIR RELATIVE ERRORS

Parameters included in regression equation	Coefficient of multiple regression (R)	Relative error (ε) %
X_1, X_5, X_6, X_9	0.939	1.72
X_4, X_9	0.928	2.43
X_1, X_2, X_4	0.925	2.52
X_4, X_5, X_9	0.915	2.38
X_4, X_5, X_7	0.907	3.97
X_2, X_3, X_5	0.905	6.76
X_7, X_9	0.895	6.43
X_7, X_8	0.890	6.43
X_5, X_6, X_7, X_8	0.890	0.19
X_6, X_7, X_8	0.812	2.69
X_4, X_7	0.807	4.23
X_3, X_9	0.820	15.89
X_2, X_9	0.791	18.28

The models can be used in practice, if they represent natural processes in maximum extent. This condition necessitates determination of model validity. The relative errors between experimented and calculated values were found based on obtained equations. And the relative errors for $Y = f(X_2, X_3, X_5)$ is given in Table-4, as an example.

R value and relative error are relatively smaller and greater consecutively in the equations including X_3, X_9 and X_2, X_9 parameters. This outcome is explained as low effect of total rainfall and irrigation water (X_9) on

TABLE-4
DIFFERENCE BETWEEN EXPERIMENTAL AND CALCULATED VALUES OF FERTILITY BASED ON Y = f (X_2, X_3, X_5) EQUATION

Y values based on fertility level		Absolute error	Relative error (%)
Experimental	Calculation		
12.10	13.09	-0.99	-8.19
18.30	19.77	-1.47	-8.01
31.50	29.11	2.39	7.59
11.40	10.01	1.39	12.19
17.10	17.16	-0.06	-0.33
30.50	31.79	-1.29	-4.24

exchangeable Na and the amount (X_3) of water resistant particles (> 0.25 mm).

The obtained relationships between productivity of cotton and dozes of fertilizer (N-X_1, P-X_2, K-X_3) are defined as following:

$$Y = 17.2 + 0.032X_1 + 0.022X_2 - 0.064X_3 \ (R = 0.924; \varepsilon = 1.33\ \%)$$

The functional relationship was derived in order to determine maximum fertility and appropriate fertilizer doze:

$$Y = 27.4 - 0.185X_1 + 0.144X_2 - 0.113X_3 + 0.000696X_1^2 - 0.000687X_2^2 + 0.00123X_3^2 \ (R = 0.99)$$

To calculate the maximum crop level from the last equation, extreme points in the equation were found from the partial derivatives of the variables X_1, X_2 and X_3 according to maximum-minimum values determination method.

The dozes of fertilizer-N (X_{1max}) 133.09 kg/ha (13.309 kg/da), P (X_{2max}) 105.12 kg/ha (10.512 kg/da) and K (X_{3max}) 45.94 kg/ha (4.594 kg/da), which are needed for obtaining maximum crop level - (Y_{max}) 20.7 s/ha (207kg/da) satisfying above first and second conditions, were calculated. The obtained theoretical maximum crop level came out to be less than fertility capacity of the field because the experiment was conducted under natural irrigation conditions.

The obtained empirical models can be used in management issues of fertility of artificially imporoved gray-meadow soils (experimented field) that are cultivated with cotton and estimation of crop to be obtained. These models can contribute to constitution of soil model sets as well.

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(*Received*: 21 June 2007; *Accepted*: 1 December 2007) AJC-6109