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Correlation Study Between Soil Nutrient Indices and Yield of Wheat and Barley in the Ganjabasar Region of Azerbaijan*

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Abstract: The objective of this study is to investigate the correlation between soils nutrient regime indices and the yield of winter wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*), the main cereal crops of the Ganjabasar region. Using experiments planning method a regional (the Ganjabasar region of Azerbaijan) conceptual and mathematical model was developed for soils fertility management. In this regional fertility model, all indices of fertility criteria of researched soils were combined in 5 blocks (agroecology, soil content, soil nutrient regime, soil properties and agromelioration). Unlike the prior models, included are Immediate Nutrient Reserve (ImdNR), Intermediate Nutrient Reserve (IntNR) and Potential Nutrient Reserve (PNR) forms to the list of criteria of soil nutrient regime block in the regional fertility model using the Gorbunov method. The majority of the correlation relations were consistent ($0.56<r<0.89$). Among the variables of soil nutrient regime, total nitrogen content, Cation Exchange Capacity (CEC), Immediate Nutrient Reserve (ImdNR) of phosphorus and potassium consistently correlated and Intermediate Nutrient Reserve (IntNR) of phosphorus and potassium were slightly correlated in yield, of which CEC and IntNR of P and K was steady but others were dynamic variations. It revealed that in the final mathematical models, 71% of wheat yield variability was accounted for variation in above dynamic indices.

Key words: Nutrient reserve forms, ImdNR, IntNR, fertility model, experiments planning method, Haplic Kastanozems, Irragri-Gleyic Kastanozem

INTRODUCTION

Identification of soil fertility parameters is essential for crop model development (Babayev, 2005; Mammadov, 1998). Soil types and subtypes in the research area are substantially diversified and their morphological and other agronomic properties are substantially distinguished. Present main objective was to reflect all properties and the fertility level of the soils (Haplic Kastanozems, Irragri-Gleyic Kastanozems and Haplic Kastanozems/light-colored) used for growing cereal crops in the regional fertility model.

Identification of soil attributes most determinant to crop yield is still a matter of debate. Tyumencev (1975) concluded that the main fertility parameters of soil should be humus, total nitrogen and phosphorus content. Gavrilyuk (1959) noted that soil natural properties (depth of humus horizons and humus reserve) can be reliable criteria relating crop yield. Nyiraneza *et al.* (2009) have studied 16 soil attributes to relate the variations in corn yield and N uptake. As a result of the stepwise regression analysis they asserted that 7 researched soil attributes appeared as primary indicators. Many researchers asserted that the dynamic and changeable indices (soil physical and chemical properties, nutrient content) should be included for yield prediction (Agbu and Olson, 1990; Babayev, 2005).

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Study of the covariance relationships among the variables using factor analysis showed that some of the variables measured (soil organic matter, pH, P, K and NO_3-N, residue cover, broadleaf and grass weed control, corn height at two dates, plant population and grain yield) could be grouped to indicate a number of underlying common factors influencing corn yields (Mallarino *et al*., 1999). These common factors were soil fertility, weed control and conditions for early plant growth. Their importance in explaining the yield variability differed greatly among fields. Saue and Kadaja (2009) concluded that use of the combined effect of polynomial parameters, indicating a dual influence of the factors, introduces additional information about the crop yield compared with the traditional use of individual variations.

Pursuant to the optimal fertility parameters should be composed of the following soil properties and regimes (Mammadov, 2007):

- Indices of soil humus supplies-humus content and composition, reserve and depth of humus layer
- Indices of soil nutrient regime-amount of plant-available nutrients
- Indices of physical properties-compactness, aggregations, field water capacity, water permeability, aeration
- Indices of soil profile structure-depth of plough layer and humus layer
- Indices of physicochemical properties-pH, cation exchange capacity and composition of the cations, base saturation

From this point of view, there was a focus placed on soil content specifically the distribution of nutrient reserve forms in order to correctly estimate production properties and fertility of the region soils.

Generally, if the content and distribution of nutrient reserve forms of phosphorus, potassium and calcium is known, it is not difficult to understand the intensity of the soil forming process and dynamics of these nutrient elements' content. The nutrient reserve forms of phosphorus, potassium and calcium can provide information about the dynamics of soil total nutrient reserve and they should be assessed as main indices for defining soil fertility.

MATERIALS AND METHODS

Description of the Study Area

The research was set up in Goranboy, Goygol and in Samukh districts (Ganjabasar region of Azerbaijan) using Haplic Kastanozems, Irragri-Gleyic Kastanozems and Haplic Kastanozems/light-colored soils respectively in years 2002-2005 (Fig. 1). The study area is characterized by xeric climate and lies 40°89' and 40°38' N latitudes and 46°13' and 46°87' E longitudes with altitude ranging between 250 and 800 m above MSL.

Methods

Both field research and laboratory analysis was conducted. In order to reflex the basic properties of the regional soils, the experimental design aimed to cover almost all fertility levels of the soils in three districts and nine villages. Totally 53 variants were tested in three replications and three repetitions. The plot size was 100 m^2 (5×20 m) and the winter wheat and barley were planted through drill sowing method.

Soil samples were taken to a depth of 60 cm in three increments (0-15, 15-30 and 30-60 cm). The soil samples were air dried and ground to pass through a 1 mm sieve for

Fig. 1: Study area in Ganjabasar region

laboratory experiments. Soil texture determination was conducted by the pipette method of Kachinsky (Shafibekov, 1964) after the removal of organic matter and carbonates. Humus content was determined by the Turin method (Shafibekov, 1964). Thus, certain amount of soil is oxidized by 0.4 N $K_2Cr_2O_7$ and the humus content of soil is calculated according to the amount of $K_2Cr_2O_7$ which is used for oxidation. Total chemical content was analyzed by means of ignition using the Arinushkina method (Arinushkina, 1970). Phosphorus, potassium and calcium content were determined spectrophotometricaly (Carl Zeiss Spekol 1200, Germany) using the phosphovanadomolybdate (EN ISO 6878:2005) and SM 3111-FAAS method.

Definition of soil nutrient reserve forms and separation of clay fractions were performed according to the Gorbunov (1978) and Mehra and Jackson (1958). According to Gorbunov (1978) the entire amount of nutrients in the soil is called the total nutrient reserve. The total nutrient reserve includes Immediate Nutrient Reserve (ImdNR), Intermediate Nutrient Reserve (IntNR) and Potential Nutrient Reserve (PNR) forms. The ImdNR is the amount of nutrients in the soils that can be tested in agrochemical water extracts and easily assimilated by agricultural plants. The IntNR is the ash elements in clay fraction (<0.001 mm) of soils and this reserve can be assimilated by plants in case of lacking in ImdNR. PNR is the amount of nutrient elements that found in the content of soil fraction >0.001 mm. This nutrient reserve is less active and its uptake by plants requires long time. This reserve form is gradually transferred into IntNR and ImdNR as result of soil forming process as time goes on. Pursuant to the Gorbunov method the nutrient reserve forms are calculated on the basis of total amount of the nutrients in soil, the nutrients in the content of agrochemical water extracts and the nutrients in the content of <0.001 mm fraction that its percentage quantity is known in soils. Total nutrient reserve = ImdNR+IntNR+PNR. In this study, the ImdNR is equivalent to the nutrient quantity in the content of agrochemical water extracts. The IntNR is calculated by the way of multiplying the milligram quantity of nutrients in the fraction <0.001 mm by the percentage of this fraction in soil and dividing into 100. The PNR is found by subtracting the ImdNR and IntNR from the total nutrient reserve. Samples (1.0 g) were grinded and treated with 40 mL 0.3 M sodium citrate and 5 mL 1 N sodium bicarbonate. The reaction was performed in a water bath at 80°C and 0.5 g sodium hydrosulfite ($Na_2S_2O_4$) was added to the sample (Mehra and Jackson, 1958). After one minute stirring the sample was digested in a water bath for 14 min. Iron-free samples were centrifuged at 6000 rpm for 5 min, clay separates being removed. The XRD studies were carried out using XZG-4A diffractometer (Karl Zeiss. Jena Co., Germany). The 001 reflections were obtained following air drying, ethylene glycol saturation and heating at 550°C using Cu-Fe radiation (50 kV and 10 mA) at a step size of 2 θ (theta) and a step time of 1 sec.

Correlation study (often measured as a correlation coefficient, r) indicates the strength and direction of a linear relationship between two random variables. The correlation coefficient was defined by the formula:

$$r = \frac{n\sum_{i=1}^{n} y_i x_i - \sum_{i=1}^{n} y_i \cdot \sum_{i=1}^{n} x_i}{\sqrt{\left[n\sum_{i=1}^{n}(y_i)^2 - \left(\sum_{i=1}^{n} y_i\right)^2\right] \cdot \left[n\sum_{i=1}^{n}(x_i)^2 - \left(\sum_{i=1}^{n} x_i\right)^2\right]}}$$

where, X is the vector of independent variables (x_i) and Y of the dependent variables (y_i).

If the correlation coefficient is greater than 0.5, it means that there is a significant and steady correlation relationship, however to get more reliable results this coefficient should be greater than 0.7 (Kojevnikov, 2002).

The fertility parameters measured, which were relevant to this study, were physical clay (%), humus content (%), humus reserve in 1 m layer (t ha^{-1}) total nitrogen in topsoil (%), compactness (g cm^{-3}) total porosity (%), Cation Exchange Capacity (CEC) (mg eq 100 g^{-1}); phosphorus ImdNR, IntNR, PNR (%), potassium ImdNR, IntNR, PNR (%), calcium ImdNR, IntNR, PNR (%) and reaction of medium (pH). This information was a conceptual part of fertility modeling and used during mathematically substantiation. A soil fertility data obtained from the prior conceptual model was processed and structured on a computer using Turbo Pascal imperative and procedural programming language (Faranov, 2001), designed in 1968/9 and published in 1970 by Niklaus Wirth. Based on this data base we developed a regional conceptual and mathematical model for soils fertility using the experiments planning method (Melnikov *et al.*, 1968). In this regional fertility model, we combined all the indices of fertility criteria of the researched soils in 5 blocks (agroecology, soil content, soil nutrient regime, soil properties and agromelioration). Through this model the parameters of fertility criteria which are expressed in a range of minimum to maximum values can be managed by raising them to an optimal level and the production properties of soils can be forecasted.

RESULTS

Table 1 shows the indices of fertility criteria per soil type and ranges from minimum to maximum. As seen, the content of physical clay was observed between 59 and 61.6%. The humus content was changed between 2.0 and 2.4%. Soil compactness changed between 1.15 and 1.27 g cm^{-3}. The CEC values changed between 28.6 and 30.5 mg eq 100 g^{-1}. The maximum amount of ImdNR and IntNR of P_2O_5 was observed in Irragri-Gleyic Kastanozems as 8.1-10.5 and 15.5-42.7%, respectively. The minimum amount of IntNR of P_2O_5 was observed in Haplic Kastanozems as 16.7-21.4% and may be attributed to the high amount of the PNR

Table 1: Dynamics of fertility criteria indices of the soils used for cereal crops

		Varying interval of fertility criteria indices								
		Haplic Kastanozems			Irragri-Gleyic Kastanozems			Haplic Kastanozems/ light-colored		
Fertility criteria	Unit	Min.	Mid.	Max.	Min.	Mid.	Max.	Min.	Mid.	Max.
Soil texture (physical clay)	(%)	57.00	59.00	61.00	56.00	59.00	62.00	59.00	61.60	64.20
Humus	(%)	1.60	2.40	3.20	1.60	2.25	2.90	1.30	2.00	2.60
Humus reserve in 1 m layer	(t ha^{-1})	155.00	184.00	213.00	122.00	162.00	203.00	110.00	150.00	190.00
Total nitrogen in topsoil	(%)	0.12	0.18	0.24	0.11	0.14	0.17	0.12	0.14	0.15
Compactness	(g cm^{-3})	1.10	1.15	1.20	1.22	1.26	1.30	1.22	1.27	1.32
Total porosity	(%)	46.70	51.60	56.50	46.00	53.00	60.00	44.60	50.20	55.80
Cation exchange capacity	(mg eq 100 g^{-1})	22.50	28.60	34.70	25.9	28.70	31.50	28.10	30.50	32.90
Phosphorus										
ImdNR	(%)	6.30	6.65	7.00	8.10	9.30	10.5	5.90	6.55	7.20
IntNR	(%)	16.70	19.05	21.40	15.50	29.10	42.7	22.30	25.00	27.70
PNR	(%)	71.70	74.35	77.00	47.40	61.90	76.4	65.10	68.45	71.80
Potassium										
ImdNR	(%)	1.50	1.62	1.74	1.28	1.63	1.98	1.36	1.66	1.96
IntNR	(%)	35.31	37.21	39.10	35.80	38.65	41.50	37.50	20.78	40.05
PNR	(%)	59.31	61.25	63.19	56.52	59.72	62.92	57.99	59.30	60.60
Calcium										
ImdNR	(%)	0.70	0.93	1.15	0.70	0.95	1.20	0.80	1.00	1.20
IntNR	(%)	3.80	3.90	4.00	4.20	4.55	4.90	4.00	4.80	5.60
PNR	(%)	95.01	95.21	95.40	93.90	94.40	94.90	93.20	94.15	95.10
Reaction of medium	pH	7.10	7.65	8.20	7.80	8.10	8.40	8.00	8.15	8.30

Table 2: Correlation between crops productivity and indices of soils nutrient regime

	Correlation coefficient (r)	
Indices of soil nutrient regime	Wheat	Barley
Total nitrogen	0.89	0.75
Cation exchange capacity	0.71	0.66
ImdNR of phosphorus	0.74	0.81
IntNR of phosphorus	0.62	0.78
ImdNR of potassium	0.68	0.73
IntNR of potassium	0.56	0.69

of P_2O_5 in the content of these soils. The ImdNR of K_2O was ranged between 1.62 and 1.66%, the maximum amount belonged to Haplic Kastanozems/light-colored soils. The maximum amount of K_2O was observed in Irragri-Gleyic Kastanozems as 35.8-41.5%, whereas the minimum amount of PNR of K_2O is also appeared in Haplic Kastanozems/light-colored soils as 57.99-60.6%. The amount of ImdNR and IntNR of Ca was ranged as 0.93-1.0 and 3.9-4.8%, respectively. The maximum amount of ImdNR and IntNR of Ca was found in Haplic Kastanozems/light-colored soils. Haplic Kastanozems contained the maximum amount of PNR of Ca as 95.01-95.4%. The minimum amount of PNR of Ca was varied between 93.2 and 95.1% in Haplic Kastanozems/light-colored soils. The soil pH was changed between 7.1 and 8.2 in Haplic Kastanozems and the highest pH value was in Haplic Kastanozems/light-colored soil as 8.0-8.3. The highest pH value of these soils may be associated with chemical composition of parent material. Because the parent material for these soils are calcareous rocks and it changes the soil pH towards alkaline.

The correlation coefficient (r) was defined between the studied parameters of nutrient regime of soils and productivity of winter wheat and barley, the main crops of the Ganjabasar region (Table 2). The majority of correlations between parameters of soil nutrient regime and crop productivity were strong and very strong ($0.56<r<0.89$). Among the variables of soil

Table 3: The conceptual fertility model of the soils of the Ganjabasar region

Soil fertility blocks	Haplic Kastanozems M	Haplic Kastanozems Range	Irragri-Gleyic Kastanozems M	Irragri-Gleyic Kastanozems Range	Haplic Kastanozems/ light-colored M	Haplic Kastanozems/ light-colored Range
Agroecology block						
Total sunshine (kcal cm^{-2})	126	124-128	126	124-128	126	124-128
Σ>10°C (°C)	3450	3200-3700	4014	3860-4167	4014	3860-4167
Rainfall (mm)	500	400-600	300	200-400	300	200-400
Possible evaporation (mm)	700	600-800	900	800-1000	900	800-1000
Hydrothermal coefficient	0.7	0.6-0.8	0.55	0.5-0.6	0.55	0.5-0.6
Soil content block						
Content of physical clay (%)	59	57-61	59	56-62	61.6	59.0-64.2
Content of clay fraction (%)	22.1	21.0-23.2	25.5	24-27	23.7	22.0-25.4
Humus content (%)	2.4	1.6-3.2	2.3	1.6-2.9	2.0	1.3-2.6
humus reserve in 1 m layer (t ha^{-1})	184	155-213	163	122-203	150	110-190
SiO_2 (%)	56.2	55.36-57.04	56.0	55.40-56.53	56.2	55.87-56.44
Al_2O_3 (%)	22.4	21.76-23.03	21.0	20.01-22.03	21.4	20.95-21.81
Fe_2O_3 (%)	10.6	10.33-10.87	10.6	10.34-10.90	11.0	10.62-11.34
Soil nutrient regime block						
Total nitrogen (%)	0.18	0.12-0.24	0.14	0.11-0.17	0.14	0.12-0.15
Cation exchange capacity (mg eq 100 g^{-1})	28.6	22.5-34.7	28.7	25.9-31.5	30.5	28.1-32.9
ImdNR of phosphorus (%)	6.7	6.3-7.0	9.3	8.1-10.5	6.6	5.9-7.2
IntNR of phosphorus (%)	19.1	16.7-21.4	29.1	15.5-42.7	25.0	22.3-27.7
ImdNR of potassium (%)	1.63	1.5-1.74	1.63	1.28-1.98	1.66	1.36-1.96
IntNR of potassium (%)	37.2	35.31-39.10	38.7	35.8-41.5	38.8	37.5-40.05
Soil properties block						
Total porosity (%)	51.6	46.7-56.5	53	46-60	50.2	44.6-55.8
Compactness (g cm^{-3})	1.15	1.1-1.2	1.26	1.22-1.3	1.27	1.22-1.32
Water capacity (%)	44.8	42.5-47.1	42.0	37.7-46.2	39.4	36.5-42.3
Reaction of medium (pH)	7.7	7.1-8.2	8.1	7.8-8.4	8.2	8.0-8.3
Agromelioration block						
Agrotechnical measures	The fields should be ploughed in depth of 25-30 cm and at least 1.0-1.5 months prior to planting of cereals. It is recommended to conduct 1-2 times cultivation in order to make the soils mellow and kill weeds		The fields should be ploughed in depth of 27-30 cm and 1-2 times cultivation and leveling measures should be done prior to planting. It is recommended to use crop rotations with 3-5 fields and catch crops		The running of tractors should be minimized for regulating the compactness of topsoil and subsoil layers. It is recommended to loosen these soils in depth of 50-60 cm in order to regulate the water-physical properties and the transformation process of nutrient elements	
Agrochemical measures	The fertilization norms should be defined according to the nutrient reserve forms and the biological properties of the crop varieties should be taken into account.It is recommended to apply 20 t manure and 60-70 kg superphosphate per ha during the autumn plow		It is recommended to apply 20 to 25 t manure and 70 to 80 kg superphosphate per ha during the autumn plow. The fertilization norms should be defined according to the biological properties of the crop varieties and the distribution of the nutrient reserve forms in the soil		It is recommended to use green manure and apply 25-30 t manure per ha. The fertilization norms should be defined according to the distribution of the nutrient reserve forms in the soil and 60% of the fertilizers should be applied during the main plough	
Ameliorative measures	The fields should be carefully leveled and cleaned from stones after the plough. The agricultural crops should be placed rightly in the region regarding the agroecological and soil conditions		If the irrigation is conducted rightly and periodically, this measure can increase the transformation of nutrient elements from immediate and potential forms into immediate forms		Irrigation methods and norms should be selected precisely and the appropriate measures (deep loosening, minimum tillage etc.) against soil compaction process are recommended	

nutrient regime, total nitrogen content, Cation Exchange Capacity (CEC), ImdNR of P and K consistently correlated and IntNR of phosphorus and potassium were slightly correlated in yield, of which CEC and IntNR of P and K was steady but others were dynamic variations. It revealed that in the final mathematical models, 71% of wheat yield variability was accounted for variation in the above dynamic indices.

The regional (the Ganjabasar region) conceptual model was developed for evaluation of soils fertility, control and forecast the soil properties. As shown in Table 3, the fertility model was reflected in 5 blocks (agroecology, soil content, soil nutrient regime, soil properties and agromelioration). The agroecology block contained the perennial climate data. These indices can be managed little in rain fed areas and some of them may be changed by amelioration measures. The soil content block included also conservative soil fertility indices. Among these fertility indices only humus content of soils can be raised little through good agricultural practices. As regards the other indices, they allowed us to evaluate the soil fertility and define the directions of positive anthropogenic impacts where possible. The soil nutrient regime and soil properties blocks contained the physicochemical soil parameters that supply plants with nutrition, water, air and heat. The parameters of these blocks can be regulated via agrotechnical and ameliorative measures. The agromelioration block contained complex agrotechnical, agrochemical and ameliorative measures. Using these measures we can manage and improve other blocks parameters as well. Especially intensive agriculture requires continuous soil protection actions and ameliorative measures.

DISCUSSION

Indices of soil nutrient regime significantly influenced the grain yield of wheat and barley. We observed consistent positive correlation between indices of soil nutrient regime (total nitrogen content, cation exchange capacity, immediate and intermediate nutrient reserve of phosphorus and potassium) and crop yield (Table 2). Vanek *et al.* (2008) similarly observed a positive and mostly conclusive relationship between the N content of soil and the crop yield. However, in order to identify reasons for inhibited wheat growth soil parameters such as pH, exchangeable cations, C_{org} and N_{tot} were determined (Splett *et al.*, 2007). Mallarino *et al.* (1996) considered several soil physical and chemical parameters in a field study and found that the lack of consistent correlation between variables is not uncommon. They found when relating crop yields to soil variables not all yield variability can be explained by the variability of the measured soil factors and that high variations in soil factors cannot always be correlated to high variations in yield. Skudra and Skudra (2004) found a negative correlation between grain yield and soil P concentration at 20-40 cm depth at the beginning of shooting into stalk. But, it occurred because of most intensive P uptake from soil to plant leaves was at beginning of shooting into ears. Walley *et al.* (2002) noted that mineral N failed to correlate with either yield or N accumulation. Total N was significantly correlated with both crop parameters but only when the entire 0 to 60 cm depth was considered. Kravchenko and Bullock (2000) concluded that yield variability is caused by a host of factors-the challenge is to identify measurable factors that, in combination, describe an agronomically useful portion of crop variability. They observed both positive and negative correlations between yield and P and K concentrations and Cation Exchange Capacity. Since, the soils in this study had relatively high P and K concentrations, the effect of P and K probably was not a limiting factor for plant growth; hence, it played a minor role in yield variability.

CONCLUSION

Unlike the prior models, ImdNR, IntNR and PNR forms were included to the list of criteria of soil nutrient regime block in the regional fertility model. Among the variables of soil nutrient regime, total nitrogen content, CEC, ImdNR of P and K consistently correlated and IntNR of P and K were slightly correlated in yield, of which CEC and IntNR of P and K was steady but others were dynamic variations. It revealed that in the final mathematical models, 71% of wheat yield variability was accounted for variation in above dynamic indices. Holistic assessment of soil fertility criteria and reflecting nutrient reserve forms in the fertility model gives an opportunity to evaluate soil fertility more precisely, to control the dynamics of soils properties and the changing of nutrient regime and at the same time to forecast these or other properties of soils. Based on the fertility model for etalon soils, complex management measures for other soils can also be developed.

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