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Research Article

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Determination of Regression Models between Yield Parameters and Some Chemical Soil Properties of Wheat Plant

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Abstract The aim of this study was to determine some physical properties of soil and agronomic characteristics of wheat plant (plant height, thousand seed weight and seed yield) grown in Turkey's Samsun Çarşamba plain, to set regression models between these properties and to determine applicability of obtained models in estimation of yield in the plain soils. In the pedotransfer model between plant height and soil parameters as EC, OM, KDK, N, P, K, $(EC)^2$, $(KDK)^2$, (N×P×K), $(OM)^2$ wasn't statistically significant (p=0.450) and regression coefficient (R = 0.617) was high. In the model between thousand seed weight of wheat and K, Fe, $(N\times P\times K)^2$, (EC×OM×KDK), $(Fe)^2$ parameters wasn't statistically significant (p=0.121) and the high regression coefficient (R=0.725) was determined. Performance of the model between wheat seed yield and $(EC)^2$, $(OM)^2$,$(KDK)^2$, $CaCO_3$, N, P, K, Fe, (EC×OM×KDK) parameters was high (R=0.741; p=0.052). R, RMSE, d ve ME were evaluated together to determine validity of the regression models between yield components and some chemical properties of soils. In general, statistical parameters were within validity limits.

Keywords Plant height, thousand seed weight, yield, chemical soil properties, regression models

1. Introduction

In order to meet nutritional needs of growing world population with existing agricultural lands, need to obtain higher yields from unit agricultural land has emerged. Increasing and estimating of yield is one of the current and primary research topics. High efficiency depends on physical, chemical and biological soil properties with various ecological, environmental and genetic factors. Determination of relationship between the physical soil properties and the agronomical indicators of plants is necessary to establish methods for preserving, estimating and increasing the efficiency [1-5]. In many studies, it was reported that plant height, thousand seed weight and seed yield varied significantly depending on genotypes, environmental conditions, sowing frequency, as well as factors such as soil properties [6-11].

It is important to create pedotransfer (regression) models between the agronomic characteristics of wheat plant and the physical soil properties and provide the possibility to be used in the estimation of the yield. Regression models have wide applications in agricultural areas such as ecology, hydrology and various engineering branches. Setting and using regression models in soil and plant ecosystems is easier and more practical than theoretical models expressed by simple differential, algebraic and partial differential equations [12-28]. The term pedotransfer function used by Bouma and van Lanen [29] was developed more understandably by Bouma in [30] and its use in soil science was demonstrated. It was emphasized that need of accepting many assumptions in setting of Pedotrasfer models [30, 31]. Parallel to the accumulation of adequate values of soil properties in soil science, the use of regression models in accordance with the purpose has emerged. With the help of these models, quantitative relations between the plant's agronomic characteristics (plant height, thousand seed weight, seed yield) and some chemical soil properties can be explained. Physical and chemical soil properties determined experimentally more easily are preferred as independent parameters in regression models set by researchers [32-36]. This research was carried out with the aim of setting regression models between the agronomic properties of wheat plant (plant height, thousand seed weight, seed yield) and some physical soil properties and to determine the applicability of the obtained models in the estimation of plant yield.

2. Materials and Methods

The research was carried out in 20 villages wheat grown representing the Çarşamba Plain in 2013-2014 by taking 20 soil and plant samples from 0-20 cm depth for each year. The research area is a delta plain formed by Yeşilırmak river in the east of Samsun province between Canik mountains and the Black Sea. The plain covers an area of 103766 hectares between 0-50 m elevations. The plain is very rich in vegetation and has 58921 hectares of agricultural land. The wheat plant is grown on an area of 1700 hectares. The plain areas are alluvial and partly colluvial. Total annual rainfall is 985.9 mm and average annual temperature is 15-17 °C. Figure 1 shows locations where soil and plant samples were taken.

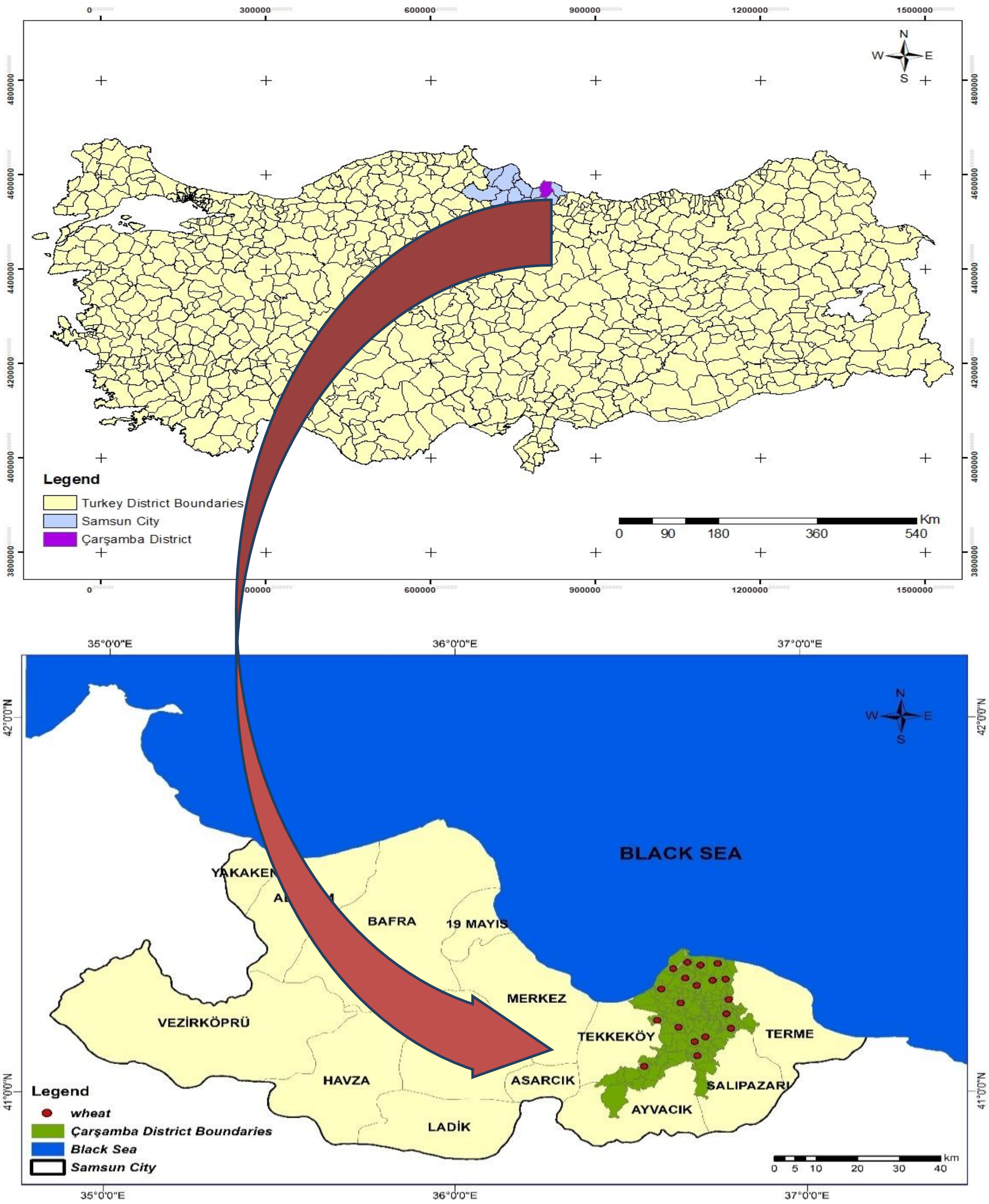

Figure 1: Locations where soil and plant samples were taken

After the soil samples were air dried and passed through 2 mm sieve, some basic soil properties were analyzed as follows. The organic carbon (OC) content was determined using the modified Walkley-Black method [37], soil reaction (pH in 1:1 soil:water suspension) by pH meter, electrical conductivity (EC25ºC) in the same soil suspension by EC meter, exchangeable cations (Ca, Mg, K, Na) by ammonia acetate extraction [37], cation exchange capacity (CEC) by Bower method [38], $CaCO_3$ content with a Scheibler Calcimeter [37], total N by Kjeldahl method [37], available phosphorus by 0.5 N $NaHCO_3$ according to blue color method [39] and extractable Fe, Mn, Zn and Cu with 0.005 M DTPA and determined using AAS [40]. Measurements related to the agronomic characteristics of the plants were made according to the Technical Instructions for Measurement of Agricultural Values Experiments of the Variety Registration and Seed Certification Center of the General Directorate of Protection and Control of the Ministry of Food and Forestry [41].

3. Statistical Analysis

Some descriptive statistics of soil and plant analysis results were calculated in SPSS 17.0statistic program and regression models formed between agronomic parameters and some chemical soil properties were made in Minitab 17.0 statistic program.

When the variation or variation coefficients are compared, it is understood that the distribution is more intense around the arithmetic mean in the data with small coefficients of variation. The root mean square error (RMSE), index of agreement (d), model efficiency (ME)were calculated using the following expressions, respectively:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - y_i\right)^2} \tag{1}$$

(where, n -is the number of data,if $n < 30$ $m = n - 1$, if $n > 30$ $m = n$; x_i - estimaded values; y_i -measured values)

$$d = 1 - \frac{\sum_{i=1}^{n}\left(x_i - y_i\right)^2}{\sum_{i=1}^{n}\left(\left|x_i - \bar{y}\right| + \left|y_i - \bar{y}\right|\right)^2} \tag{2}$$

(where, $\bar{y}$ is the mean measured values)

$$ME = 1 - \frac{\sum_{i=1}^{n}\left(x_i - y_i\right)^2}{\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2} \tag{3}$$

The root mean squares error is the standard deviation of the estimation errors. The index of agreement (d) is an indicator of the validity of the model and the d is close to 1 indicates the applicability of the model. In a study of the experimental hydrological model by Krause et al. [42], ME values were shown to vary between 1 and ∞, and if the ME was smaller than zero, the measured mean value was more effective than the calculated value. As seen in the comparison of analytical expressions of d and ME, d value is generally greater than ME [42-49].

4. Results and Discussion

4.1. Distribution of agronomic properties of wheat plant

Some descriptive statistics of some agronomic properties of wheat plant grown in the research area were given in Table 1.

Table 1: Some descriptive statistics of some agronomic properties of wheat plant (n=40)

Properties	Minimum	Maximum	Mean	Std. Deviation	CV, %	Skewness
PH, cm	66.47	113.53	82.98	11.39	0.13	1.611
TSW, g	44.52	60.11	51.51	4.05	7.86	0.259
SY, kg da^{-1}	332.72	653.66	515.17	102.10	19.81	-0.149

PH: Plant height; TSW: Thousand seed weight; SY: Seed yield; CV: Coefficient of variation.

As shown in Table 1, minimum plant height of the wheat plant was 66.47 cm, maximum plant height was113.53 cm and the average plant height was 82.98 cm. The standard deviation was 11.39; the coefficient of variation was 0.13%; the coefficient of skewness was found as 1.611. Minimumthousand seed weight of the wheat plant was 44.52 g, maximum thousand seed weight was 60.11 g and the average thousand seed weight was 51.51 g. The statistical indicators were found to be 4.05; 7.86%; 0.259, respectively.Minimum seed yield per decare of the wheat plant was 332.72 kg, maximum seed yield was 653.66 kg and the average seed yield was 515.17 kg.The standard deviation, coefficient of variation and skewness were 102.10; 19.81%; -0.149, respectively. As is seen, statistical indicators vary within valid limits.When compared to the standard deviation values of plant height and thousand seed weight, the reason for the high standard deviation of seed yield may be the wide variation of seed yield.

4.2. Regression models between the plant height of wheat and some chemicalsoil properties

Regression models between the plant height of wheat and some chemical soil properties were given in Table 2.

Table 2: Regression models between the plant height of wheat and some chemical properties of soils

	Models	R	F	p
1.	PH = 61.1 + 52.0 EC - 2.70 OM + 0.022 CEC + 12.5 N - 0.245 P + 8.49 K	0.411	0.61	0.643
2.	PH = 66.6 + 156 EC - 7.44 OM – 1.39 CEC - 109 $(EC)^2$ + 0.79 $(OM)^2$ + 0.0214 $(CEC)^2$	0.591	1.87	0.133
3.	PH = 63.9 + 144 EC - 5.1 OM - 1.30 CEC + 25.2 N - 0.023 P - 7.3 K - 94 $(EC)^2$ + 0.27 $(OM)^2$ + 0.0212 $(CEC)^2$ + 0.00405 $(N×P×K)^2$	0.617	1.05	0.450

PH: Plant height, cm; EC: Electrical conductivity, dS m^{-1}; CEC: Cation exchange capacity, cmol kg^{-1}; OM: Organic matter, %; N: Nitrogen, %; P: Phosphorus, ppm; K: Potassium, cmol kg^{-1}.

As seen from (1) - (3) regression models (Table 2) between plant height of wheat and some chemical soil properties, regression coefficients were between 0.411 and 0.617; F values were between 0.61 and 1.87; p values ranged from 0.133 to0.643. The lowest regression coefficient (R= 0.411) was found in model 1, which includes EC, OM, CEC, N, P, K parameters, while the highest regression coefficient (R= 0.617) was determined in model 3.Changing the parameters such as EC, K, OM, N in the narrow range can cause the p values to be relatively large. In other studies, it has been shown that the expression of regression models with polynomials including the square, square root and product of soil properties increases the regression coefficient of the model and thus the importance of the estimation [50, 5].

4.3. Regression models between the thousand seed weight of wheat and some chemicalsoil properties

Regression models between the thousand seed weight of wheat and some chemicalsoil properties were given in Table 3.

Table 3: Pedotransfer models between the thousand seed weight of wheat and some physical soil properties

	Models	R	F	p
1.	TSW = 56.4 + 4.52 EC + 2.16 OM – 0.184 CEC + 0.0842 Fe + 3.01 K - 63.1 N- 0.0285 P	0.659	2.19	0.080
2.	TSW = 64.9 – 7.3 EC + 0.49 OM – 0.288 CEC + 0.0945 Fe + 1.91 K - 64.0 N - 0.0000 P + 0.102 (EC×OM×CEC)	0.687	2.12	0.085
3.	TSW = 68.0 – 14.6 EC - 0.66 OM - 0.340 CEC - 65.5 N + 0.0086 P + 5.63 K + 0.174 Fe - 0.00204$(N×P×K)^2$ + 0.148 (EC×OM×CEC) - 0.00100 $(Fe)^2$	0.725	1.88	0.121

TSW: Thousand seed weight, g; EC: Electrical conductivity, dS m^{-1}; CEC: Cation exchange capacity, cmol kg^{-1}; OM: Organic matter, %; N: Nitrogen, %; P: Phosphorus, ppm; K: Potassium, cmol kg^{-1}; Fe: Iron, ppm.

As seen from (1) - (3) regression models (Table 3) between thousand seed weight of wheat and some physical soil properties, regression coefficients were between 0.659 and 0.725; F values were between 1.88 and 2.19; p values are generally within the significant tendency and range from 0.080 to 0.121.The regression coefficient (R= 0.659) was found to be the lowest in the model 1, including the parameters EC, OM, CEC, N, P, K with TSW and the highest regression coefficient (R= 0.725) was found in model 3, which included the square and multiplication of some soil parameter values. Ekberli and Dengiz [5] conducted a study; The regression coefficients of the regression models formed by some physical and chemical properties of the various horizons of the soils formed on different topographic positions have been reported to vary between 0.615-0.998, and the organic matter, clay, Ca + Mg properties have an effect on the increase of CEC.

4.4. Regression models between the seed yield of wheat and some chemicalsoil properties

Regression models between the seed yieldof wheat and some chemicalsoil properties were given in Table 4.

Table 4: Regression models between the seed yield of wheat and some chemicalsoil properties

	Models	R	F	p
1.	SY = 466 - 167 EC + 8.65 $CaCO_3$ + 889 N - 1.92 Fe + 0.12 $(OM)^2$	0.658	3.36	0.021
2.	SY = 372 + 50 $(EC)^2$ + 8.96 $(OM)^2$ + 0.0563 $(CEC)^2$ + 7.89 $CaCO_3$ + 941 N – 2.03 Fe - 2.92 (EC×OM×KDK)	0.702	2.78	0.034
3.	SY = 318 + 408 $(EC)^2$ + 15.3 $(OM)^2$ + 0.0614 $(CEC)^2$ + 8.70 $CaCO_3$ + 923 N - 2.20 P + 59.0 K - 2.45 Fe - 4.37 (EC×OM×CEC)	0.741	2.44	0.052

SY: Seed yield, kg da^{-1}; EC: Electrical conductivity, dS m^{-1}; CEC: Cation exchange capacity, cmol kg^{-1}; OM: Organic matter, %; N: Nitrogen, %; P: Phosphorus, ppm; K: Potassium, cmol kg^{-1}; $CaCO_3$: Lime, %.

As seen from (1)-(3) regression models (Table 3) between seed yield of wheat and some chemicalsoil properties, regression coefficients were between 0.658 and 0.741; F values were between 2.44 and 3.36; p values ranged from 0.021 to 0.052.The regression coefficient (R= 0.658) was found to be the lowest in the model 1, including the parameters EC, $CaCO_3$, OM, N Fe with SY and the highest regression coefficient (R= 0.741) was found in model 3, which included the square and multiplication of some soil parameter values. p values were statistically significant ($p < 0.05$). Budka et al. [51] used regression equations to estimate yield losses due to fungal disease infection in agricultural practice. The researchers reported that the regression coefficients (R) ranged from 0.077 to 0.343, and that the soil and climatic conditions of the region and leaf type should be taken into account in estimating the decrease in yield.

4.5. The validity of regression models formed between the agronomic parameters and some chemicalsoil properties

In determining the validity of the regression models obtained according to the experimental data, it is necessary to use the values different from the values that set the model or from the values in the data bank [49]. Statistical parameters for determining the validity of regression models between wheat plant height, thousand seed weight and seed yield with some chemical properties of soils were given in Table 5.

Table 5: Some descriptive statistics of regression models of plant height, thousand seed weight and seed yield

Models (No)	R	RMSE	d	ME
PH (3)	0.617	9.235	0.975	-2.660
TSW (3)	0.725	2.973	0.988	-0.595
SY (3)	0.741	59.204	0.992	0.231

PH: Plant height; TSW: thousand seed weight; SY: Seed yield; R:Regression coefficient; RMSE: Root mean square error; d: index of agreement; ME: Model efficiency.

The statistical parameters of regression models formed between the agronomic parameters and soil properties were determined by using the soil and agronomic properties of 28 different areas of the research area.As shown in Table 5, descriptive statistics of regression models are generally within the validity limits. In Figure 2, comparison of calculated and measured values of plant height, thousand seed weight and seed yield of wheat according to the third model were given.

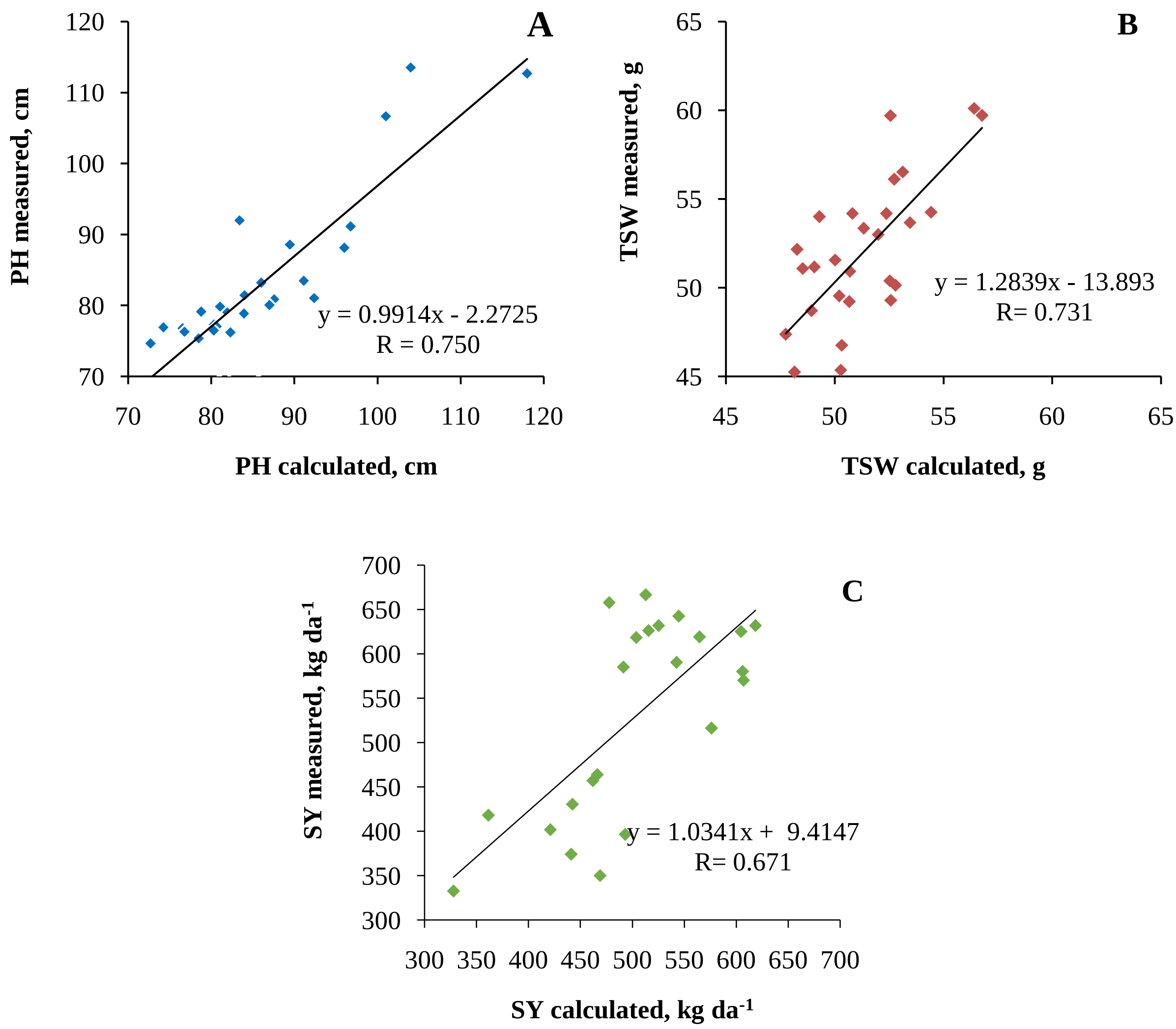

Figure 2: The relationship between calculated and measured plant height (A), thousand seed weight (B), seed yield (C) and physical soil properties according to regression models

5. Conclusion

In this study, some chemicalsoil properties and the agronomic characteristics of the wheat plant grown in Turkey's Samsun Çarşamba plain were determined, regression models were set between the agronomic properties of plants and some chemical soil properties and the applicability of the models were shown. Change in chemicalsoil properties is one of the factors that have a significant effect on plant yield. Factors such as the lack of regular agricultural applications (fertilization, irrigation, etc.) and the change of climatic conditions cause the chemical properties not to be within optimum limits and change rapidly. As is seen from the values of the regression coefficients, it is possible to use the regression models in the research area to estimate the agronomic factors in the wheat grown soils. Moreover, the performance of the 3rd models (Table 2-4) is higher. Considering the ease of implementation of regression models, in order to set regression models at the local and regional level, it is necessary to create soil and plant data bank suitable for the purpose. In general, in setting of models between yield and soil properties, the applicability of the model becomes more difficult if the parameters are many (> 10-15). The use of regression models in the form of polynomials including the square, square root and multiplying of the soil properties values increases the validity of the model. Considering the validation of the different processes by the statistical parameters, it is more appropriate to evaluate the R, RMSE, *d*, ME together in determining the validity of the models. The experimental data used in the setting of the regression models should be different from the values used in determining the validity of the models.

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