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ORIGINAL PAPER

Evaluation of plant characteristics related to grain yield of FAO410 and FAO340 hybrids using regression models

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Abstract

In breeding programs, estimation of increase in yield based on changes in effective plant traits is of great importance, which can be identified using regression modeling. The regression model refers to the prediction of the value of a dependent variable from the values of one or more independent variables. This study evaluated morphological traits of maize (FAO410) on six treatments of fertilizer in 2 years in Debrecen University by the regression model. This experiment was RCBD with four replications in the Látókép zone. Treatments were included in different levels of fertilizer: nitrogen, phosphor, and potassium. The regression model was significant at one percent that showed morphological traits have a straight effect on the yield of maize in FAO410 and FAO340. Grain yield had a positive correlation with plant height, outer ear diameter, the weight of ear, weight of cob, number of leaves, weight of all seeds in each ear, the weight of one thousand seeds on FAO410, and grain yield had a positive correlation with plant height, stem diameter, outer ear diameter, the weight of ear, weight of cob, number of seeds in each column, weight of all seeds in each ear, weight of the fresh plant in a hectare, the weight of one thousand seeds on FAO340 too. Cluster analysis showed the traits classification on two groups on hybrids. Reach maximum grain yield require the evaluation of yield components and their effect.

Keywords Regression model · Cluster analysis · Grain yield · Correlation

Introduction

Cereals are the most important food crop on the planet, supply 70% of the people's food, and provide 75% of the total energy and more than half of the protein needed by humans (Emam 2007). Corn is high on grain and dry matter yield, having a varied nutritional value in the supply of carbohydrates, and edible oils in the agricultural economy of different countries are of particular importance (Nagy 2006). Maize (*Zea Mays* L.) as a staple food and forage crop has grown under a wide range of climates worldwide (Wang et al. 2008) and throughout much of the New World (Mexico, Central America, and South America) is an important plant. It is also the third-largest crop after wheat and rice in terms of area under cultivation and production (Kumar 2014).

Conventional farming practices in today's world have not led to an acceptable success in resource management because of over-reliance on artificial inputs and injections of auxiliary energy such as fertilizers and pesticides; it has created unstable crop ecosystems (Cociu and Alionte 2017; Roberts 2008). Access to quantities and types of fertilizer can absorb more elements from the soil and transfer it to the seed, which is essential to optimize fertilizer consumption and improve product quality (Anjum et al. 2007). Climatic factors and nutrients play an important role in accelerating this genetic potential (Eichelberger et al. 1989; Asghari and Hanson 1984).

Nitrogen is one of the most important nutrients that has a major impact on maize grain yield (Borjian and Emam 2000). Inadequate nitrogen management is one of the important factors that reduce corn yield. Choosing the best method of nitrogen fertilizer is important for maximum yield and reduction of negative environmental impacts (Izadi and Emam 2010). Researchers have reported an increase in maize grain yield by increasing the amount of NPK chemical

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fertilizers due to the plant's greater access to nutrients; also, it has shown that mineralization of soil organic matter alone cannot fully meet plant nutrition needs (Karimi et al. 2011). Other researchers have reported increasing quantitative and qualitative characteristics of maize under the influence of NPK chemical fertilizers (Akbari et al. 2005; Kogbe and Adediran 2003; Mostafavi et al. 2013; Hejazi et al. 2013; Bramdeo et al. 2019; Mousavi et al. 2013, 2019a, b).

Some researchers also reported that the effect of different levels of fertilizer application on fertilizer use efficiency in maize was significant. Therefore, the amount of fertilizer was increased from zero to 120%; this is the recommended amount in NPK fertilizer combination, which can decrease the amount of fertilizer use efficiency. The results showed that using treatment 80% of recommended fertilizer with an average of 21 kg/kg and 120% recommended fertilizer with an average of 11 kg/kg had the highest and lowest fertilizer use efficiency, respectively (Karimi et al. 2007).

Considering the importance of achieving sustainable agricultural goals to reduce the use of chemical fertilizers and to achieve more efficient use of resources through optimal input management, it is necessary to evaluate the effect of chemical fertilizers on these factors. Therefore, this experiment is conducted to estimate the effect of NPK chemical fertilizers on the quantitative and qualitative yield and trace element productivity in maize. Simple correlation, multiple regression and path analysis are used to analyze the components of yield and grain yield (Fraser 1983). Various methods exist for analyzing the yield components; the selection of the appropriate method is purely for research. One of these methods is the stepwise regression analysis. Identification of appropriate traits can be the basis of selection in breeding programs, and it can be useful to maximize grain yield (Pirzadeh Moghaddam et al. 2014).

Materials and methods

The study was carried out at the Debrecen Agricultural Research Station, 121 m above sea level in 2018 and 2019. The experiment was conducted in a randomized complete block design with four replications with maize hybrids (FAO340, FAO410). Treatments include NPK1 (N:0, P2O5:0, K2O:0), NPK2 (N:30, P2O5:23, K2O:27), NPK3 (N:60, P2O5:46, K2O:54), NPK4 (N:90, P2O5:69, K2O:81), NPK5 (N:120, P2O5:92, K2O:108), NPK6 (N:150, P2O5:115, K2O:135) in this experiment. The total rainfall from May until October was 291 mm in 2018 and 279 mm in 2019. April had a favorable effect on the partly dry and warm, but there was not fit value of precipitation until May (93.9 mm) due to the condition of the dried seedbed (Fig. 1). Sowing was performed on April 24, 2018, and April 25, 2019, in a long-term experiment. Plant density was 72.000 plants per hectare.

The traits include green seeker (GR), chlorophyll meter (SP), plant height (HP), stem diameter (SD), outer ear diameter (OD), number of nodes (NN), the weight of ear(WE), the weight of cob (WC), number of seeds in each row (NSR), number of seeds in each column (NSC), number of leaves (LN), length of the ear (LE), weight of all seeds in each ear (WSE), number of seed in each ear (NSE), the weight of the fresh plant in hectare (WFP), weight of one thousand seeds (1S), grain yield (GY). The regression analysis and correlation analysis were performed with Genstat and Minitab software.

Regression refers to the prediction of the value of a dependent variable from the values of one or more independent variables. In general, the purposes of regression analysis are calculating the behavior of variable Y based on variable X: that is, by changing the X scores in the subjects, what behavior does the variable Y represent?.

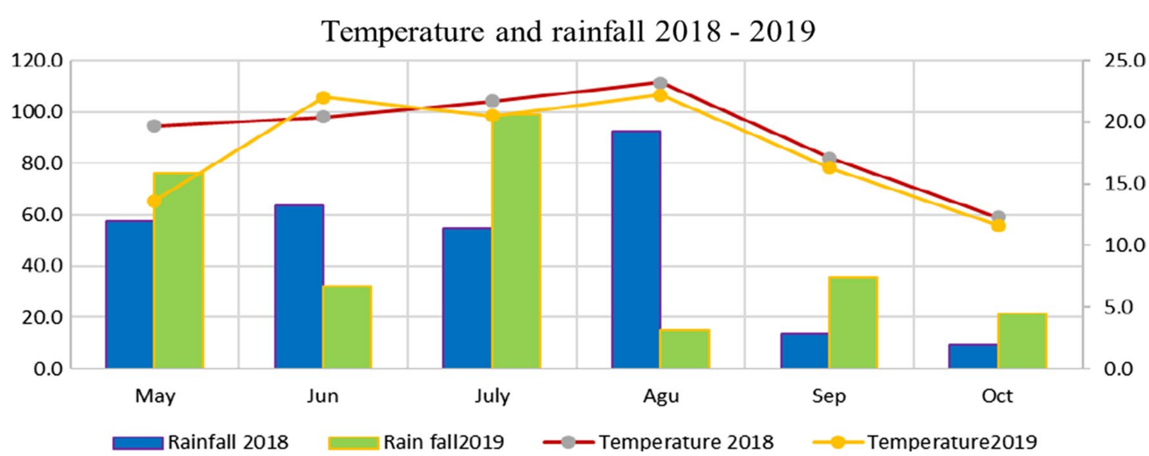

Fig. 1 Monthly mean temperature and precipitation in 2018 and 2019

This behavior may be linear or curved. Data-based prediction for future samples is the data mining through statistical methods. The relative importance of each of the independent variables is estimated in predicting the dependent variable. Multivariate regression can investigate the unique effect of one or more predictor variables after controlling for one or more covariates.

Stepwise Method: In the step-by-step approach, it enters the variables one by one into the model. That is, the variable that has the highest correlation coefficient with the dependent variable is the first that entered into the analysis. In this method, the researcher does not enter the order of the variables.

In multivariate statistical analysis, there are different computational methods to measure the dependence or relationship between two random variables. The correlation between two variables is the ability to predict the value of one according to the other. One way of showing the relationship between the two variables is to calculate the "covariance" and "correlation coefficient" between them.

Regression and correlation are closely related. Also, regression is called the return to mean. The amount of correlation between the two variables determines the magnitude of the regression coefficient. Regression to the mean occurs when the correlation between the two variables is not complete. The accuracy of the prediction depends on the strength of the correlation. The higher the correlation between variables, the more accurate the prediction

Tryon used the term cluster analysis in 1939 for methods of grouping objects that were similar. Cluster analysis is a data analysis shortcut tool that aims to arrange different objects into groups whose degree of correlation between two objects if they belong to a group is maximum and otherwise minimal. In other words, cluster analysis shows the structure of the data without explaining what exists (Rezaei 2007).

The objective of this study was to reach information about yield components by the regression model and find the best condition for the maximum yield on FAO410 and FAO340 hybrids.

Results

Regression model

The results of the regression analysis of variance for FAO410 and FAO340 hybrids showed that the regression model for trait hybrids was significant at one percent level. This means that the regression model, the slope of the line and the regression line equation can be investigated for effective traits on maize grain yield in hybrids. Also, the coefficient of determination was on FAO410 hybrid 89.05% and FAO340 hybrid 90.08% (Table 1).

Stepwise regression analysis of variance in FOA410 hybrid shows that in the first treatment (control) the traits length of ear and weight of ear, in the second treatment, traits weight of one thousand seeds and weight of cob, in the third treatment stem diameter and number of leaves, in the fourth treatment number of nodes and weight of ear, in the fifth treatment weight of ear and stem diameter and in the sixth treatment stem diameter and weight of ear had the maximum effect on maize grain yield. Reach to maximum grain yield must be paying attention to traits in treatments. For example, the weight of the ear and stem diameter had the highest effect on grain yield in the fourth and fifth treatments. When using this treatment, more attention is paying to the trait of the weight of ear and stem diameter for maximum grain yield. Also, these results in the FAO340 hybrid show that maximum grain yield on traits of first treatment (control) effect on plant height and the number of seed in each ear, the second treatment effect on stem diameter and weight of all seeds in each ear, the third treatment effect on the number of seeds in each column and number of leaves, the fourth treatment effect on the number of seeds in each row and weight of one thousand seeds, the fifth treatment effect on the number of leaves and outer ear diameter and the sixth treatment effect on the number of leaves and number of nodes. These traits had the most far-reaching effect on FAO340 maize grain yield. In this case, for the fifth treatment, traits including the number of leaves and outer ear diameter will have the most comprehensive effect on maize grain yield in FAO340 (Table 2).

Correlation analysis

In this research, the correlation analysis showed in FAO410 hybrid that chlorophyll meter with number of leaves, green seeker with number of seed in each ear, plant height with number of leaves, stem diameter, weight of ear, number of nodes, weight of cob, number of seeds in each column, length of ear, weight of all seeds in each ear, number of seed in each ear and grain yield, number of leaves with stem diameter, number of nodes, weight of ear, weight of cob, weight of all seeds in each ear and grain yield, stem diameter

Table 1 Regression analysis of traits' hybrids

Hybrids	Model	*df*	F-Value	R^2 (%)
FOA 410	Regression model	17	23.49**	89.05
	Error	30	62.22	
	Total	47	277.83	
FAO340	Regression model	17	15.49**	90.08
	Error	30	75.86	
	Total	47	222.55	

Significant one percent (**), significant five percent (*)

Table 2 Stepwise regression analysis of treatments in hybrids

Hybrids	Treatments	Regression equation	Parameters
FAO410	NPK1 (N: 0, P2O5:0, K2O:0)	Y = 7.27 − 0.103 X1 − 0.115 X2	X1: weight of ear, X2: length of ear
FAO410	NPK2 (N:30,P2O5:23,K2O:27)	Y = 6.381 + 0.610 X1 + 0.459 X2	X1: weight of one thousand seeds, X2: weight of cob
FAO410	NPK3 (N:60,P2O5:46,K2O:54)	Y = 9.76 − 0.61 X1 + 0.284X2	X1: leaves number, X2: stem diameter
FAO410	NPK4 (N:90,P2O5:69,K2O:81)	Y = 5.782 + 0.532 X1 + 0.454 X2	X1: number of nodes (pcs), X2: weight of ear
FAO410	NPK5(N:120,P2O5:92,K2O:108)	Y = −4.64 + 0.712 X1 + 0.568 X2	X1: weight of ear, X2: stem diameter
FAO410	NPK6(N:150,P2O5:115,K2O:135)	Y = 128.5 − 15.60 X1 − 17.69 X2	X1: weight of ear, X2: stem diameter
FAO340	NPK1 (N: 0, P2O5:0, K2O:0)	Y = 6.194 + 0.3288 X1 − 0.0708 X2	X1: number of seed in each ear, X2: plant height
FAO340	NPK2 (N:30,P2O5:23,K2O:27)	Y = 3.617 + 0.380 X1 + 0.416 X2	X1: weight of all seeds in each ear, X2: stem diameter
FAO340	NPK3 (N:60,P2O5:46,K2O:54)	Y = 10.088 − 1.385 X1 − 0.921 X2	X1: number of seeds in each column, X2: leaves number
FAO340	NPK4 (N:90,P2O5:69,K2O:81)	Y = 2.84 + 4.62 X1 − 0.404 X2	X1: number of seeds in each row, X2: weight of 1000 grain
FAO340	NPK5(N:120,P2O5:92,K2O:108)	Y = 6.916 − 0.6756 X1 − 0.4184 X2	X1: leaves number, X2: outer ear diameter (cm)
FAO340	NPK6(N:150,P2O5:115,K2O:135)	Y = 1.344 − 0.9484 X1 + 2.314 X2	X1: number of nodes (pcs), X2: leaves number

with number of nodes, number of seeds in each column, length of ear and weight of fresh plant in hectare, outer ear diameter with weight of ear, weight of all seeds in each ear, number of seed in each ear, weight of one thousand seeds and grain yield, weight of ear with weight of cob, weight of all seeds in each ear, weight of one thousand seeds and grain yield, weight of cob with number of seeds in each column, weight of all seeds in each ear, number of seed in each ear and grain yield, number of seeds in each column with length of ear, number of seed in each ear and weight of fresh plant in hectare, length of ear with weight of fresh plant in hectare, weight of all seeds in each ear with weight of one thousand seeds and grain yield, weight of one thousand seeds with grain yield have significant one percent positive correlation together. Also, stem diameter with a weight of one thousand seeds and weight of the fresh plant in hectare with the weight of one thousand seeds have a negative significant correlation on one percent level (Table 3).

In FAO340, there is a positive correlation on one percent level with traits that include plant height with number of leaves, stem diameter, number of nodes, weight of ear, weight of cob, weight of all seeds in each ear and grain yield, number of leaves with stem diameter and number of nodes, stem diameter with outer ear diameter, number of nodes, weight of cob, weight of ear, length of ear, weight of fresh plant in hectare and grain yield, outer ear diameter with number of nodes, weight of ear, weight of cob, number of seeds in each column, length of ear, weight of all seeds in each ear, number of seed in each ear, weight of fresh plant in hectare, weight of one thousand seeds and grain yield, number of nodes with weight of cob, weight of ear with weight of cob, weight of all seeds in each ear, number of seed in each ear, weight of fresh plant in hectare, weight of one thousand seeds and grain yield, weight of cob with length of ear, weight of all seeds in each ear, weight of one thousand seeds and grain yield, number of seeds in each column with weight of all seeds in each ear, number of seed in each ear, weight of fresh plant in hectare, weight of one thousand seeds and grain yield, length of ear with number of seed in each ear, weight of all seeds in each ear with number of seed in each ear, weight of fresh plant in hectare, weight of one thousand seeds and grain yield, number of seed in each ear with weight of fresh plant in hectare and grain yield, weight of one thousand seeds with grain yield and weight of fresh plant in hectare with grain yield. Also, the number of nodes with the number of seeds in each row and the weight of fresh plant with the weight of one thousand seeds have a significant negative correlation on one percent (Table 4). In the evaluation of grain yield, the study on correlation between traits and effect of traits together is important.

Cluster analysis

Cluster analysis is a statistical method for grouping data or observations, according to their similarity or degree of proximity. Through cluster analysis, the data or observations are divided into homogenous and distinct categories. Two groups exist in grouping affect traits of grain yield by cluster analysis in this research. In FAO410, the first group includes chlorophyll meter, number of leaves, number of nodes, green seeker, number of seeds in each column, number of seed in each ear, plant height, length of ear, stem diameter, the weight of the fresh plant in hectare and number of seeds in each row that have effect on growth process in plant and grain formation. The second group includes outer ear diameter, the weight of one thousand seeds, and the weight of ear, weight of all seeds in each ear and weight of cob that affect ear and grain of ear (Fig. 2). In FAO340, the first group of traits includes chlorophyll meter, outer ear diameter, the weight of the fresh plant in a hectare, length of ear, number of seeds in each column, number of seed in each ear, green

Table 3 Correlation analysis of FAO410

	GR	HP	LN	SD	OD	NN	WE	WC	NSR	NSC	LE	WSE	NSE	WFP	1S	GY
SP	0.194	0.312*	0.392**	0.314*	0.108	0.329*	0.229	0.357*	– 0.066	0.304*	0.205	0.242	0.135	0.036	0.120	0.261
GR		0.275	0.321*	0.081	0.112	0.345*	0.143	0.327*	0.062	0.360*	0.148	0.141	0.424**	0.024	0.007	0.98
HP			0.617**	0.546**	0.242	0.560**	0.406**	0.510**	0.183	0.550**	0.595**	0.385**	0.466**	0.361*	−0.018	0.371**
LN				0.443**	0.315*	0.901**	0.445**	0.389**	0.078	0.367*	0.249	0.409**	0.313*	0.179	0.219	0.452**
SD					0.103	0.488**	0.002	0.295*	– 0.126	0.402**	0.532**	−0.029	0.262	0.809**	−.370**	0.046
OD						0.290*	0.578**	0.234	0.316*	0.228	0.223	0.564**	0.404**	−0.101	0.438**	0.378**
NN							0.292*	0.307*	0.057	0.341*	0.240	0.248	0.277	0.252	0.143	0.256
WE								0.606**	0.164	0.321*	0.082	0.978**	0.327*	−0.144	0.553**	0.867**
WC									0.002	0.581**	0.262	0.587**	0.528**	0.221	−0.043	0.508**
NSR										– 0.064	– 0.156	0.144	0.259	– 0.212	0.116	0.003
NSC											0.396**	0.299*	0.858**	0.412**	– 0.072	0.313*
LE												0.072	0.310*	0.431**	– 0.139	0.009
WSE													0.309*	– 0.183	0.547**	0.860**
NSE														0.259	– 0.111	0.235
WFP															– .553**	– 0.152
1S																0.551**

Green seeker (GR), chlorophyll meter (SP), plant height (HP), number of leaves (LN), length of ear (LE), stem diameter (SD), outer ear diameter (OD), number of nodes (NN), the weight of ear(WE), the weight of cob (WC), number of seeds in each row (NSR), number of seeds in each column (NSC), length of the ear (LE), weight of all seeds in each ear (WSE), number of seed in each ear (NSE), the weight of the fresh plant in hectare (WFP) weight of one thousand seeds(1S), grain yield (GY). Significant one percent (**), significant five percent (*)

Table 4 Correlation analysis of FAO340

	GR	HP	LN	SD	OD	NN	WE	WC	NSR	NSC	LE	WSE	NSE	WFP	1S	GY
SP	− 0.062	− 0.052	− 0.059	− 0.005	0.299*	− 0.046	− 0.002	0.005	− 0.079	0.298*	0.090	0.003	0.170	0.283	0.098	0.254
GR		0.160	0.164	0.262	0.216	0.256	0.191	0.209	− 0.002	0.278	0.083	0.179	0.242	0.029	0.229	0.086
HP			0.503**	0.653**	0.244	0.451**	0.401**	0.503**	0.020	0.247	0.108	0.371**	0.220	0.191	0.152	0.475**
LN				0.630**	0.353*	0.860**	0.197	0.367*	− 0.272	0.171	0.294*	0.154	0.049	0.147	0.326*	0.325*
SD					0.454**	0.691**	0.401**	0.666**	− 0.144	0.332*	0.503**	0.342*	0.321*	0.372**	0.239	0.520**
OD						0.376**	0.418**	0.543**	0.049	0.375**	0.506**	0.379**	0.437**	0.575**	0.370**	0.487**
NN							0.313*	0.516**	− .398**	0.159	0.420**	0.261	0.004	0.217	0.261	0.276
WE								0.825**	− 0.066	0.364*	0.194	0.994**	0.464**	0.437**	0.702**	0.669**
WC									− 0.111	0.249	0.441**	0.764**	0.307*	0.350*	0.472**	0.546**
NSR										− 0.309*	− 0.293*	− 0.058	0.167	0.070	− 0.099	− 0.006
NSC											0.231	0.376**	0.637**	0.408**	0.379**	0.475**
LE												0.147	0.387**	0.313*	0.017	0.124
WSE													0.475**	0.437**	0.722**	0.671**
NSE														0.518**	0.251	0.521**
WFP															− .384**	0.693**
1S																0.595**

Green seeker (GR), chlorophyll meter (SP), plant height (HP), number of leaves (LN), length of ear (LE), stem diameter (SD), outer ear diameter (OD), number of nodes (NN), the weight of ear(WE), the weight of cob (WC), number of seeds in each row (NSR), number of seeds in each column (NSC), length of the ear (LE), weight of all seeds in each ear (WSE), number of seed in each ear (NSE), the weight of the fresh plant in hectare (WFP) weight of one thousand seeds(1S), grain yield (GY). Significant one percent (**), significant five percent (*)

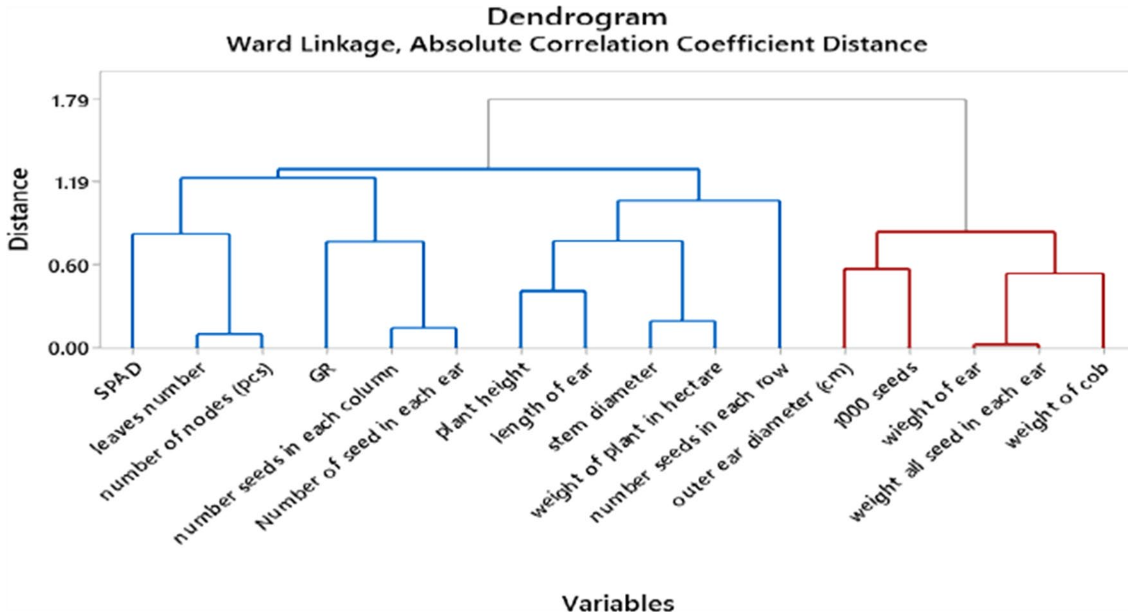

Fig. 2 Cluster analysis of FAO410 traits

seeker and number of seeds in each row that affect ear and grain of ear. The second group involves plant height, stem diameter, number of leaves, number of nodes, the weight of ear, weight of all seeds in each ear, the weight of cob and weight of one thousand seeds; these traits have impression on vegetative stage and grain production (Fig. 3).

Discussion

Regression analysis showed that the weight of ear is an effective trait for grain yield on FAO410 and the number of leaves is an effective trait for grain yield on FAO340. Accordingly, to reach maximum grain yield on different treatments, the charge of this trait could get an acceptable yield on hybrids. Researchers using stepwise regression in maize hybrid cultivars investigated grain yield as a dependent variable against

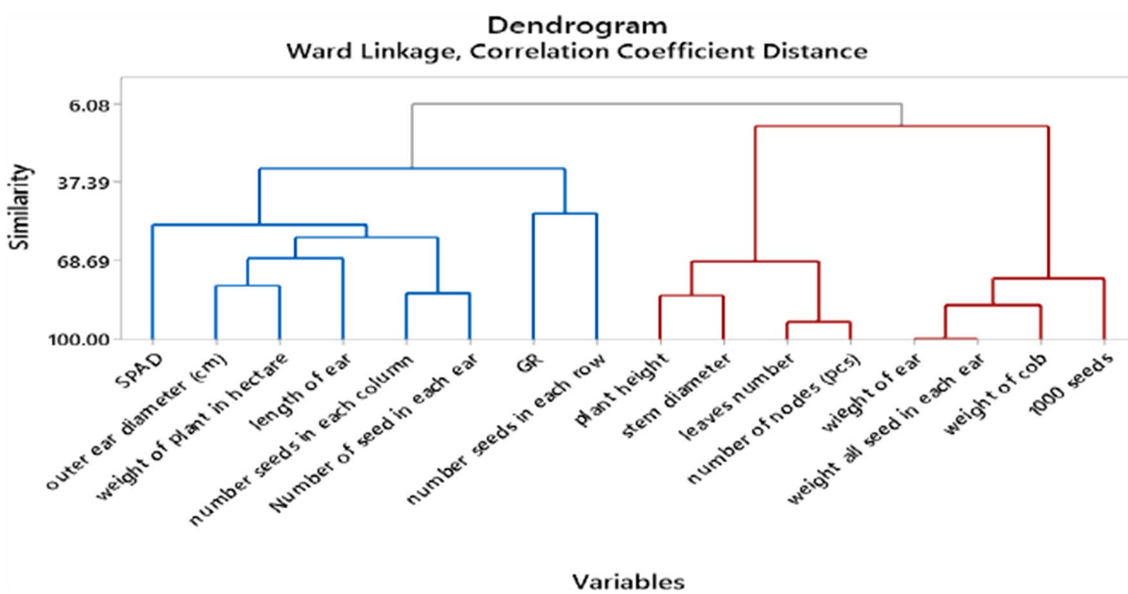

Fig. 3 Cluster analysis of FAO340 traits

other traits as the independent variable. (Zinali et al. 2004). In the final model of multiple regression analysis, one thousand grain weight, number of seeds per ear, number of leaves and plant height were important traits of research (Mostafavi 2013). Based on correlation analysis, effective traits on grain yield in FAO410 hybrid include plant height, outer ear diameter, the weight of ear, weight of cob, number of leaves, weight of all seeds in each ear, weight of one thousand seeds. On the other hand, if you want to get maximum grain yield on this hybrid, we can control growth of these traits. Also, effective traits on FAO340 hybrid include plant height, stem diameter, outer ear diameter, the weight of ear, the weight of cob, number of seeds in each column, weight of all seeds in each ear, the weight of the fresh plant in a hectare, the weight of one thousand seeds. Extensive studies have been conducted to determine the correlation and analysis of genetic parameters of grain yield through the components of yield. Grain yield is a complex trait controlled by various morphological and physiological traits (Crosbie and Mock 1981). Thus, genetic control of yield is indirectly influenced by traits that are correlated with yield and increasing yield and improving its genetic characteristics is a function of various morphological and physiological traits. Understanding the correlation between yield and its components and finding the type of relationship between them can increase grain yield (Kalla et al. 2001). Another study also reported that grain yield had a positive and significant correlation with plant height, ear height and number of ear rows per ear (Sadek et al. 2006). In correlation analysis, some traits do not have a significant relationship with yield, and in regression analysis, some variables do not have a significant effect on the function (Farshadfar 1998). The results of stepwise regression analysis of maize showed that weight of one thousand grain yield and cob weight with negative coefficients, and the depth of planting and plant height with positive coefficients, justified 52% of total changes in grain yield and have been identified as effective traits in increasing grain yield (Amiri et al. 2009). In another study, it was reported that grain yield had a positive and significant correlation with plant height, ear height and number of rows in the ear (Sadek et al. 2006). Cluster analysis showed that breeding seeds and plant or reach the highest yield must be which part of the plant is significant, or have the maximum effect of the other parts. Morphological traits of maize by cluster analysis showed that area of the flag leaf, grain rows, peduncle length out of flag leaf and ear conicalness index were important traits of 25 traits on this experience (Choukan et al. 2005). The purpose of this study was to investigate the grain yield differences between FAO410 and FAO340 hybrids in Hungary. As we know, the yield is controlled by multigenes. So to increase yield, attention needs to be paid to more traits. Therefore, it will be difficult to control multigenes or traits of work. This study tries to facilitate the study of yield by clustering traits and classification of the traits. Therefore, the effective traits of yield are classified into two groups. In correlation and regression analyses, the interaction effects of traits with each other as well as the slope of the regression line have identified the traits that had the greatest effect on grain yield. Through studying (reducing or increasing) traits, maximum grain yield can be achieved in two hybrids and different levels of fertilizer to gain optimal stability yield. Breeders can also use the result of the research to study the effects on yield as well as plant breeding. Overall, to test the viability of these hybrids, it will require 3 years of testing, which will be reported soon.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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