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# RELATIONSHIPS BETWEEN SELECTED TRAITS IN MAIZE (*Zea mays* L.). PART 2. MULTIPLE LINEAR REGRESSION

*Summary*

*The study comprised of 13 maize cultivars, evaluated at two years in a randomized complete block design, with four replicates. To assess the quantitative impact of individual traits on the grain yield the multiple regression analysis was used. We observed grain yield and seven quantitative traits: SPAD, length of ears, number of kernels in row, damage of maize caused by P. nubilalis, infection of maize by Fusarium spp., number of ears and content of chlorophyll a.*
***Key words:*** *maize, multiple linear regression, grain yield*

# WSPÓŁZALEŻNOŚĆ POMIĘDZY WYBRANYMI CECHAMI KUKURYDZY (*Zea mays* L.). CZĘŚĆ 2. LINIOWA REGRESJA WIELOKROTNA

*Streszczenie*

*Badanie obejmowało 13 odmian kukurydzy, analizowanych w dwóch latach w doświadczeniach polowych, w układzie bloków losowanych kompletnych, w czterech powtórzeniach. Do oceny wpływu poszczególnych cech ilościowych na plon ziarna zastosowano analizę funkcji regresji wielokrotnej. Obserwowano plon ziarna i siedem cech ilościowych: SPAD, długość kolby, liczba ziaren w rzędzie, procent roślin uszkodzonych przez P. nubilalis, porażenie przez Fusarium, liczba kolb oraz zawartość chlorofilu a.*
***Słowa kluczowe:*** *kukurydza, liniowa regresja wielokrotna, plon ziarna*

## 1. Introduction

Despite the great progress in recognizing the requirements and agricultural practices of maize, farmers still face a number of problems. Environmental requirements are increasing and environmental regulations are tightening. Rising prices of means of production, mineral fertilizers in particular, mean that cost reductions need to be sought in cultivation technologies, better use of the components contained in mineral fertilizers [9, 10] (e.g. by applying Mg and Zn) and farm organic fertilizers [11]. The production potential of maize (*Zea mays* L.) is very high. The yield of grain to be obtained is currently estimated at 32.0 t·ha$^{-1}$. The maximum grain yield (15% $H_2O$) in the USA was 28.5 t·ha$^{-1}$, i.e. 75% of the potential yield. Assuming that the harvest index (HI) is about 50% for maize, the collected biomass can amount even to 60 t fw·ha$^{-1}$ [5, 7]. The amount of yield determined at 695 million tons, places maize at the head of the global cereal harvest, and its subspecies *Zea mays* L. ssp *saccharata* is on the list of the six most frequently consumed vegetables in the United States [4, 8]. The obtained yield is the result of interaction of environmental and genetic factors. Beneficial changes have taken place in both aspects in terms of cultivation. These are global warming and breeding progress. In addition to rice, wheat and sugar cane, maize is the plant that is most often utilized to produce food products in the world [13]. There are numerous maize hybrids in the selection for cultivation, therefore research studies comparing them gain great importance. Polish maize breeding is competitive with foreign companies, and successive cultivars are being registered in European Union countries and beyond its borders.

Therefore, the aim of the study was to apply multiple linear regression to assess the relationships between grain yield and selected maize traits.

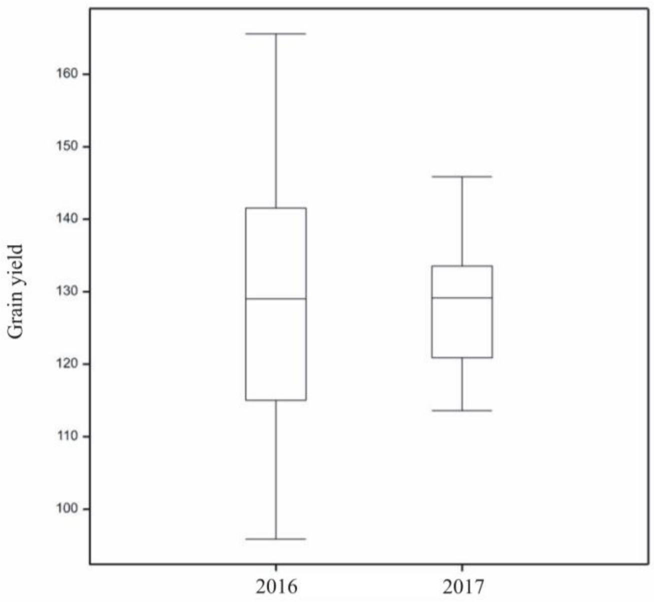
## 2. Material and Methods

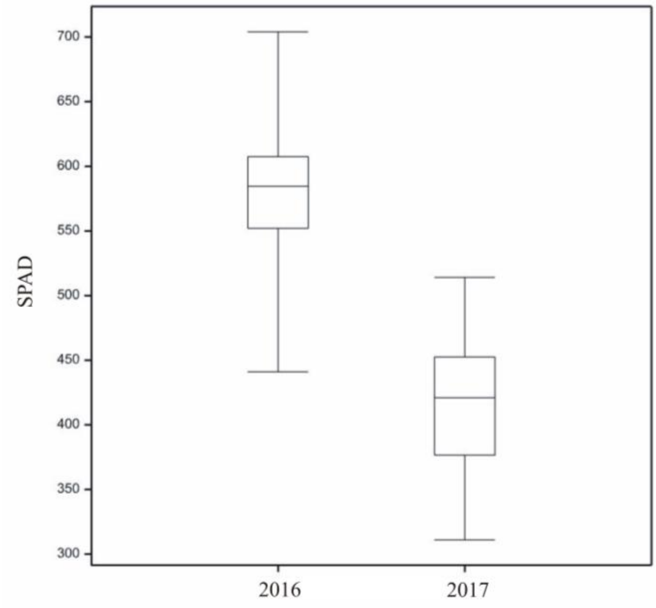
### 2.1. Experimental field

The field experiment was carried out at the Department of Agronomy, the Poznań University of Life Sciences, in 2016 and 2017 in the fields of the Agricultural Experimental Station in Swadzim. Thirteen cultivars (NK Cooler, Delitop, Gazele, NK Ravello, ES Palazzo, ES Paroli, SY Cooky, Drim, Clarica, PR 39 G12, SY Mascotte, ES Fortran, PR 39 K 13) of fodder maize, grown for grain and purchased from different seed production companies, were compared.

### 2.2. Plant material

In this paper we analyzed eight quantitative traits: grain yield (dt/ha) (Fig. 1), SPAD (Fig. 2), length of ears (cm) (Fig. 3), number of kernels in row (Fig. 4), damage of maize caused by *Pyrausta nubilalis* Hbn. (Fig. 5), infection of maize by *Fusarium* spp. (Fig. 6), number of ears (no./m$^2$) (Fig. 7) and chlorophyll *a* content (Fig. 8).

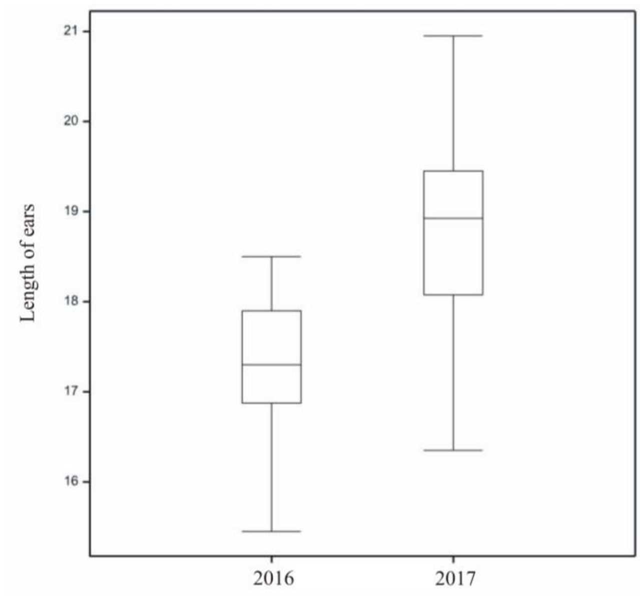



*Source: own study / Źródło: opracowanie własne*

Fig. 1. Boxplot of the grain yield of 13 maize cultivars in two years of study
*Rys. 1. Wykres pudełkowy obrazujący plon ziarna 13 odmian kukurydzy w dwóch latach prowadzenia doświadczeń*

Fig. 2. Boxplot of the SPAD of 13 maize cultivars in two years of study
*Rys. 2. Wykres pudełkowy obrazujący SPAD 13 odmian kukurydzy w dwóch latach prowadzenia doświadczeń*



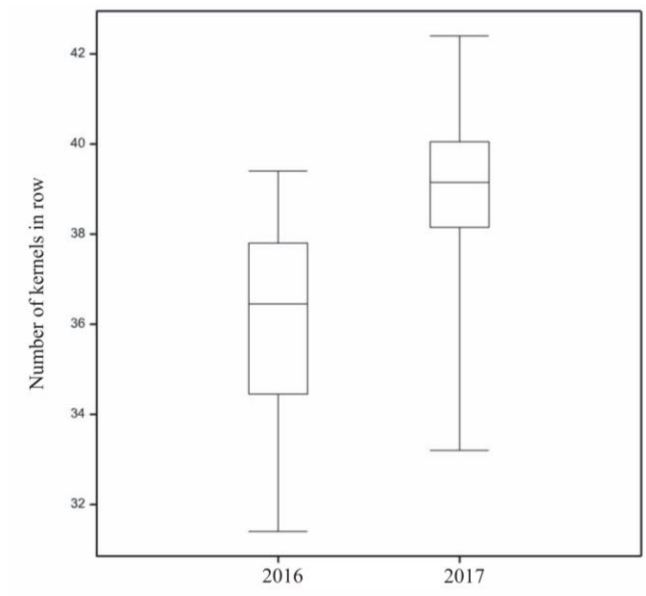




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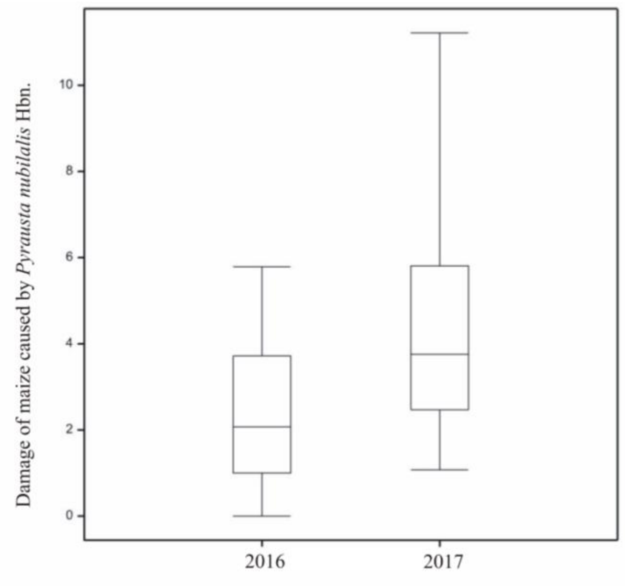
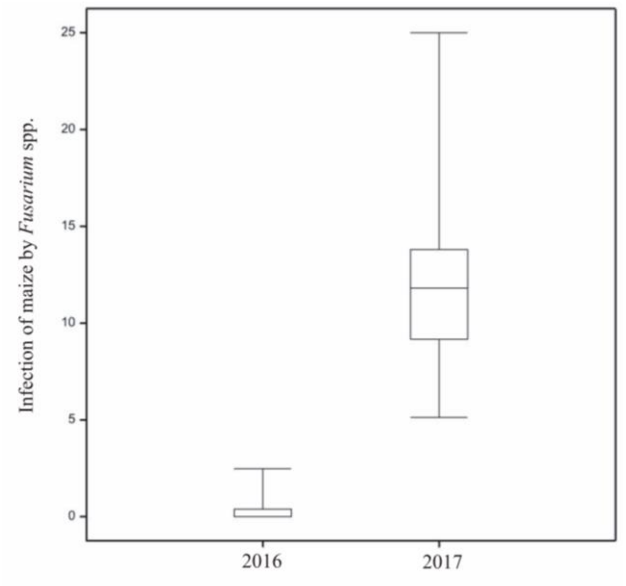
Fig. 3. Boxplot of the length of ears of 13 maize cultivars in two years of study
*Rys. 3. Wykres pudełkowy obrazujący długość kolb 13 odmian kukurydzy w dwóch latach prowadzenia doświadczeń*

Fig. 4. Boxplot of the number of kernels in row of 13 maize cultivars in two years of study
*Rys. 4. Wykres pudełkowy obrazujący liczbę ziaren w rzędzie 13 odmian kukurydzy w dwóch latach prowadzenia doświadczeń*

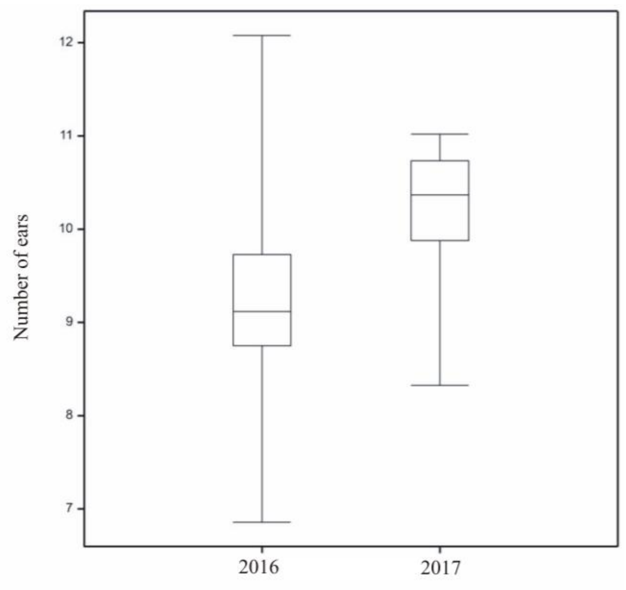


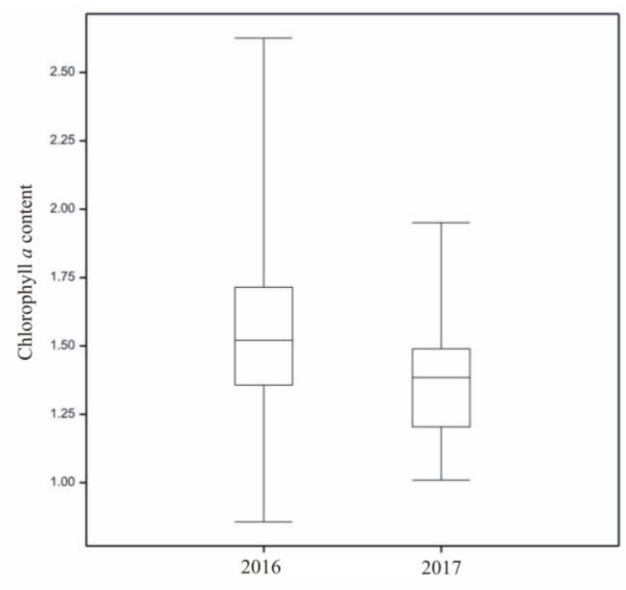




*Source: own study / Źródło: opracowanie własne*

Fig. 5. Boxplot of the damage of maize caused by *Pyrausta nubilalis* Hbn. of 13 maize cultivars in two years of study
*Rys. 5. Wykres pudełkowy obrazujący procent roślin uszkodzonych przez Pyrausta nubilalis 13 odmian kukurydzy w dwóch latach prowadzenia doświadczeń*

Fig. 6. Boxplot of the infection of maize by *Fusarium* spp. of 13 maize cultivars in two years of study
*Rys. 6. Wykres pudełkowy obrazujący porażenie przez Fusarium 13 odmian kukurydzy w dwóch latach prowadzenia doświadczeń*




*Source: own study / Źródło: opracowanie własne*

Fig. 7. Boxplot of the number of ears of 13 maize cultivars in two years of study
*Rys. 7. Wykres pudełkowy obrazujący liczbę kolb 13 odmian kukurydzy w dwóch latach prowadzenia doświadczeń*

Fig. 8. Boxplot of the chlorophyll *a* content of 13 maize cultivars in two years of study
*Rys. 8. Wykres pudełkowy obrazujący zawartość chlorofilu w 13 odmianach kukurydzy w dwóch latach prowadzenia doświadczeń*

### 2.3. Statistical analysis

The analysis of relationships between grain yield and the other examined traits was carried out with the use of the multivariate regression analysis. Selection of traits was done by using a forward-backward stepwise, multiple linear regression with a probability into and out of the model of 0.05. The analyses were conducted for each year separately. The coefficients of determination were used to measure how the model fitted the data.

## 3. Results and Discussion

Maize crop plays an important role in the world economy and is valuable ingredient in manufactured items that affect a large proportion of the world population. Relationship studied between grain yield and yield components and other quantitative traits is prerequisite to plan a meaningful breeding programme [1]. In the first year of observation the grain yield was determined only by number of kernels in row and infection of maize by *Fusarium* spp. (Table 1).

Table 1. Characteristics significantly affecting the grain yield of maize
*Tab. 1. Cechy wpływające istotnie statystycznie na plon ziarna kukurydzy*

| Year | 2016 | | 2017 | |
|---|---|---|---|---|
| Source of variation | d.f. | Mean squares | d.f. | Mean squares |
| Model | 2 | 107506*** | 3 | 71477*** |
| Residual | 11 | 99.07 | 10 | 12.44 |
| Total | 13 | 16623 | 13 | 16504 |
| Variety | Estimate of partial regression coefficients | | Estimate of partial regression coefficients | |
| Regression content | ns | | ns | |
| SPAD | ns | | ns | |
| Length of ears | ns | | -6.93** | |
| Number of kernels in row | 3.40*** | | 5.48** | |
| Damage of maize caused by *P. nubilalis* | ns | | ns | |
| Infection of maize by *Fusarium* spp. | 16.89* | | ns | |
| Number of ears | ns | | 4.46* | |
| Chlorophyll *a* content | ns | | ns | |
| Percentage variance accounted | 55.10% | | 76.70% | |
| Standard error of observations | 9.95 | | 3.53 | |
| * $p$<0.05; ** $p$<0.01; *** $p$<0.001 | | | | |

*Source: own study / Źródło: opracowanie własne*

In 2017 length of ears, number of kernels in row and number of ears influence on grain yield. Similar results obtained Annapurna et al. [2] which found that grain yield was positively and significant correlated with plant height, ear girth, number of seed row and number of rows ear. You et al. [15] reported significant relationships between yield and number of rows ear, number of grains row and 1000-grain weight. The percentage of phenotypic variation explained by the traits were equal to 55.10% in 2016 and 76.70% in 2017 (Table 1).

Maize grain yield is the result of a series of processes in which its individual components are formed, namely 1) number of ears per unit of area, 2) number of grains in the ear and 3) 1000 grain weight. The number of grains in an ear is the product of the number of grains in a row and the number of rows of grains in an ear. The number of ears per unit area of single-ear cultivars is determined before maize sowing, during the planning of crop density. The development of crop components such as the number of grains in the ear and thousand grain weight is determined by the availability of water and nitrogen for the plant throughout the entire growing season as well as factors modifying their efficiency. Formation of the basic component of the grain yield, i.e. the ear starts in maize already from the 3-leaf stage (BBCH 13) and lasts to the 5-leaf phase (BBCH 15). The number of leaves and ears with spikelet primordia is determined during this period [14]. Potentially, maize can develop up to 8 ears simultaneously. The number of developing ears depends on the genotype and the availability of water and nutrients, mainly nitrogen [6]. Usually only the top 1-2 ears become dominant and develop further. Nitrogen availability shapes the grain yield from the ear by affecting the number of formed grains and preventing their reduction after fertilization [3]. Most often, simple correlation coefficients are applied to determine the relationship between grain yield and elements of its structure. Many authors indicate that the relationships between plant traits revealed during ontogenesis are better described by path analysis coefficients [12]. These authors reported that in the case of the traditional variety, a positive, direct effect on the amount of grain yield was exerted by 1000 seed weight and the number of production ears per unit of area. The number of grains in the ear exerted a smaller, and at the same time negative direct effect on the effect variable (grain yield). For the “stay-green” type hybrid, the largest positive direct effect on the grain yield was exerted by the number of production ears per unit of area. The number of grains in the ear and 1000 seed weight had a lower direct but positive effect on the effect variable.

## 4. Conclusions

1. The grain yield of maize cultivars is determined by various traits, depending on thermal and moisture conditions.
2. The number of kernels in row influence on grain yield of maize cultivars independing on thermal and moisture conditions.
3. The multiple linear regression is very good tool to assess the relationships between grain yield and selected quantitative maize traits. The percentage of phenotypic variation explained by the traits were equal to 55.10% in 2016 and 76.70% in 2017.

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