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RELATIONSHIPS BETWEEN SELECTED TRAITS IN MAIZE (*Zea mays* L.). PART 1. LINEAR AND RANK CORRELATIONS

Summary

The objective of this study was to assess the relationships between grain yield and selected traits in maize linear Pearson correlation coefficients and Spearman's rank correlation coefficients. The study comprised of 13 maize cultivars, evaluated at two years in a randomized complete block design, with four replicates. The linear and rank correlation coefficients were shown in tables and as figures for easier observation of their tendency and significance.
Keywords: maize, linear correlation, rank correlation

WSPÓŁZALEŻNOŚĆ POMIĘDZY WYBRANYMI CECHAMI KUKURYDZY (*Zea mays* L.). CZĘŚĆ 1. KORELACJA LINIOWA I RANGOWA

Streszczenie

Celem badań było zastosowanie współczynników korelacji liniowej Pearsona i rangowej Spearmana do oceny współzależności pomiędzy plonem ziarna i wybranych cech kukurydzy. Badanie obejmowało 13 odmian kukurydzy, analizowanych w dwóch latach w doświadczeniach polowych, w układzie bloków losowanych kompletnych, w czterech powtórzeniach. Współczynniki korelacji liniowej i rangowej przedstawiono w tabelach oraz w postaci wykresów umożliwiających łatwe zaobserwowanie ich kierunku i istotności.
Słowa kluczowe: *kukurydza, korelacja liniowa, korelacja rangowa*

1. Introduction

Maize in Poland is one of the basic forage plants enabling the balance of energy and protein in the nutrition of all animal groups. In addition to the genetic factor, nitrogen fertilization determines the amount of obtained yields [3]. Maize has high nutritional and fertilizing requirements, especially for nitrogen, and at the same time it is not very sensitive to an overdose of this component [5]. For this reason, doses of nitrogen fertilizers applied in maize agricultural practice are often higher than it would appear from factual requirements. In addition, maize cultivation in wide rows means that mineral components applied on the surface in mineral fertilizer are no longer available when the plant eventually forms a deep root system that is able to absorb them [6]. Księżak et al. [7] have reported that the use of high nitrogen doses, especially in light soils, poses a threat to the environment, as it may lead to nitrate concentration in soil, groundwater contamination and eutrophication of water reservoirs. Therefore, in order to take full advantage of maize yielding potential, we must apply nutrients, including nitrogen, so that their uptake by maize follows the rhythm of its growth [10]. The most common use of maize in Poland is for grain or silage. When selecting a grain cultivar, one should ensure that the variety has a favorable ratio of grain weight to mass of the rest of the plant, a fast grain drying characteristic in the field and a large proportion of grain weight in the total ear weight [11]. It is beneficial if the ears are set at one level, which makes combine-harvesting easier. On the other hand, cultivars with high digestibility of organic matter and high energy content in the aboveground part of the plant are suitable for silage. The dry matter content should be in the range of 30-35% at the time of silage, while the ear percentage in the yield should exceed 50%. Very often, the cultivars are characterized by versatile application and are intended for both directions of use. When choosing a cultivar, it is important to note whether it has the "stay green" trait [9]. Thanks to this, plant leaves retain their greenness longer, providing nutrients. Such cultivars yield higher in grain production, while silage is more digestible. In addition, the "stay green" cultivars possess increased disease resistance [2, 10]. There are numerous maize hybrids in the selection for cultivation, therefore research studies comparing them gain great importance. Correlation analysis is one of the methods used to compare the characteristics of individual cultivars.

Therefore, the aim of the study was to apply Pearson's linear and Spearman's rank correlation coefficients 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 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: SPAD, grain yield (dt/ha), lenght of ears (cm), number of kernels in row, damage of maize caused by *Pyrausta nubilalis* Hbn., infection of maize by *Fusarium* spp., number of ears (no./m^2) and content of chlorophyll *a*.

2.3. Statistical analysis

The procedures FCORRELATION and SPEARMAN in GenStat Release 18 were used for the, respectively, linear Pearson and rank Spearman correlation analyses. The analyses were conducted for each year separately.

3. Results and Discussion

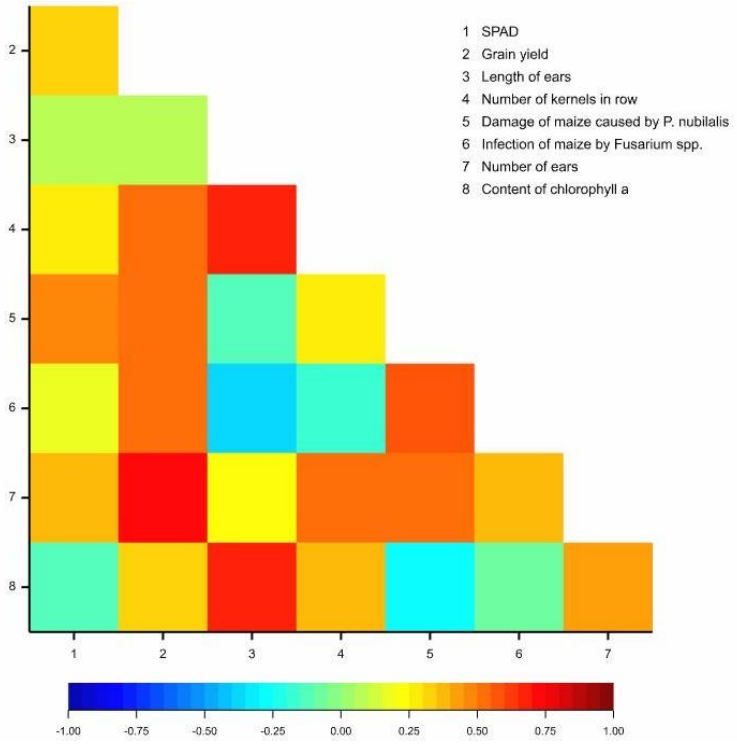
In the first year of study we observed linear correlations between grain yield and number of ears (0.74), length of ears and number of kernels in row (0.69), length of ears and content of chlorophyll *a* (0.67), as well as damage of maize caused by *P. nubilalis* and infection of maize by *Fusarium* spp. (0.56) (Tab. 1, Fig. 1). Rank correlations between traits studied in 2016 were observed for: number of kernels in row and length of ears (0.60), number of ears and grain yield (0.74), number of ears and number of kernels in row (0.68), and content of chlorophyll *a* and length of ears (0.61) (Tab. 1, Fig. 2). The linear correlation between number of ears and number of kernels in row was not observed (Tab. 1, Fig. 1). Similarly, the rank correlation between damage of maize caused by *P. nubilalis* and infection of maize by *Fusarium* spp. was not observed in 2016 (Tab. 1, Fig. 2).

Table 1. Linear Pearson correlation coefficients (above diagonal) and Spearman's rank correlation coefficients (below diagonal) for the traits studied in 2016

Tab. 1. Współczynniki korelacji liniowej Pearsona (powyżej przekątnej) i współczynniki korelacji rangowej Spearmana (poniżej przekątnej) dla cech badanych w 2016 roku

Trait	SPAD	Grain yield	Length of ears	Number of kernels in row	Damage of maize caused by *P. nubilalis*	Infection of maize by *Fusarium* spp.	Number of ears	Content of chlorophyll *a*
SPAD	1	0.34	0.09	0.29	0.5	0.18	0.35	-0.12
Grain yield	0.25	1	0.08	0.51	0.5	0.52	0.74**	0.31
Length of ears	0.06	0.03	1	0.69**	-0.1	-0.39	0.23	0.67*
Number of kernels in row	0.41	0.46	0.60*	1	0.3	-0.17	0.52	0.35
Damage of maize caused by *P. nubilalis*	0.45	0.39	-0.22	0.13	1	0.56*	0.53	-0.28
Infection of maize by *Fusarium* spp.	0.52	0.54	-0.38	0.06	0.5	1	0.35	-0.08
Number of ears	0.43	0.74**	0.29	0.68*	0.5	0.39	1	0.43
Content of chlorophyll *a*	-0.1	0.21	0.61*	0.3	-0.2	-0.28	0.4	1
* $p<0.05$; ** $p<0.01$								

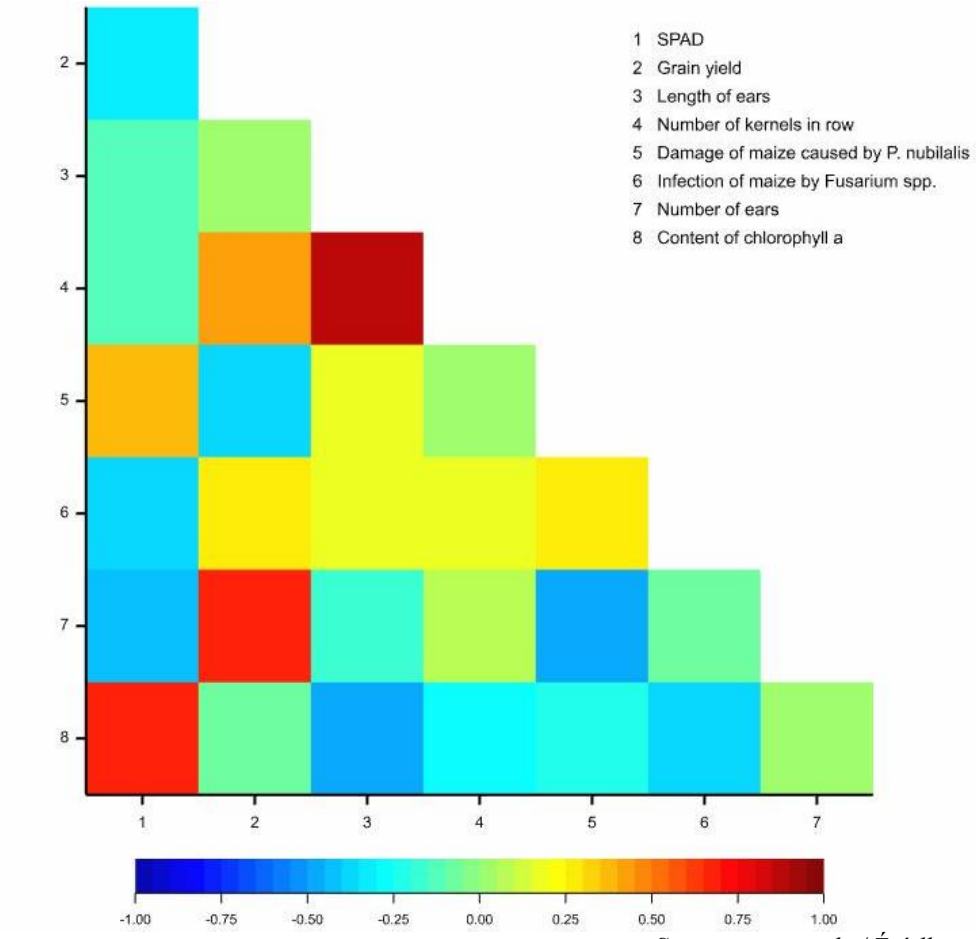
Source: own study / Źródło: opracowanie własne



Source: own study / Źródło: opracowanie własne

Fig. 1. Heatmap for linear Pearson's correlation coefficients between observed traits in 2016 ($r_{critical}$=0.55)

Rys. 1. Mapa ciepła współczynników korelacji liniowej Pearsona pomiędzy cechami obserwowanymi w 2016 r. (r_{kr}=0,55)



Source: own study / Źródło: opracowanie własne

Fig. 2. Heatmap for Spearman's rank correlation coefficients between observed traits in 2016 ($r_{critical}$=0.55)
Rys. 2. Mapa ciepła współczynników korelacji rangowej Spearmana pomiędzy cechami obserwowanymi w 2016 (r_{kr}=0,55)

In the second year of study we observed both linear Pearson (r_P) and Spearman rank (r_S) correlations between: length of ears and number of kernels in row (r_P = 0.85, r_S = 0.86), SPAD and content of chlorophyll *a* (r_P = 0.66, r_S = 0.68) as well as grain yield and number of ears (r_P = 0.65, r_S = 0.65) (Tab. 2, Figs. 3 and 4).

Different results were obtainted by Ghimire et al. [4] and Abadassi [1]. Abadassi [1] observed not significantly correlation between grain yield and number of ears. Ghimire et al. [4] obtained statistically significant correlation between SPD and grain yield. Opposite to our results, significant correlation between infection of maize by *Fusarium* spp. and grain yield, obtained Nagy et al. [8].

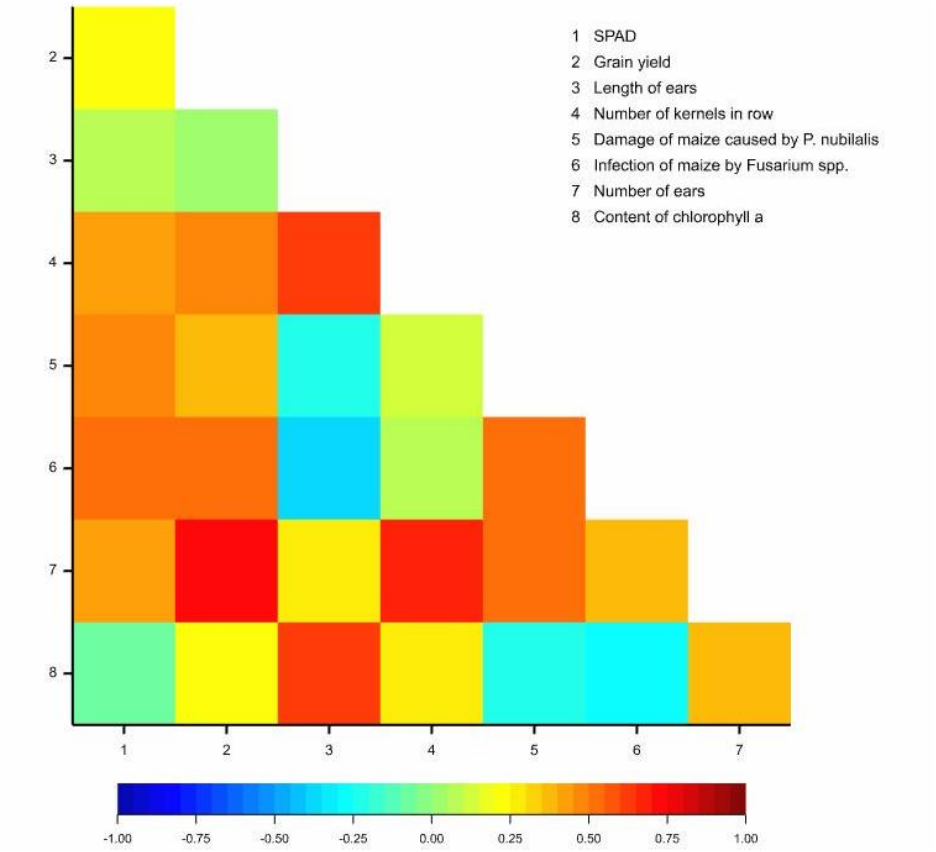
4. Conclusions

1. Linear and rank correlations can describe different relationships between observed traits.
2. In conditions observed in 2017 linear and rank relationships between studied traits were equal.

Table 2. Linear Pearson's correlation coefficients (above diagonal) and Spearman's rank correlation coefficients (below diagonal) for the traits studied in 2017
Tab. 2. Współczynniki korelacji liniowej Pearsona (powyżej przekątnej) i współczynniki korelacji rangowej Spearmana (poniżej przekątnej) dla cech badanych w 2017 roku

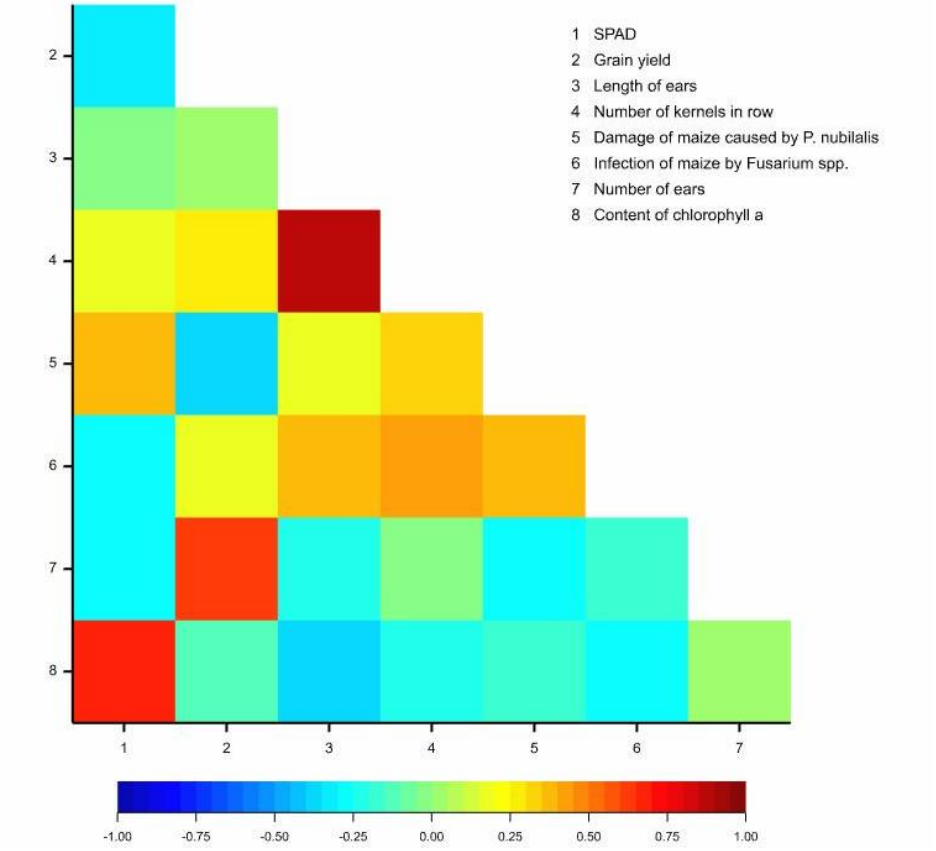
Trait	SPAD	Grain yield	Length of ears	Number of kernels in row	Damage of maize caused by *P. nubilalis*	Infection of maize by *Fusarium* spp.	Number of ears	Content of chlorophyll *a*
SPAD	1	-0.34	-0.12	-0.1	0.38	-0.4	-0.44	0.66*
Grain yield	-0.32	1	0.01	0.44	-0.4	0.27	0.65*	-0.09
Length of ears	-0.01	0.01	1	0.85***	0.17	0.17	-0.19	-0.46
Number of kernels in row	0.15	0.3	0.86***	1	0.03	0.2	0.06	-0.29
Damage of maize caused by *P. nubilalis*	0.36	-0.35	0.19	0.3	1	0.28	-0.48	-0.23
Infection of maize by *Fusarium* spp.	-0.26	0.2	0.35	0.41	0.36	1	-0.07	-0.36
Number of ears	-0.29	0.65*	-0.23	-0.05	-0.3	-0.2	1	0.02
Content of chlorophyll *a*	0.68*	-0.12	-0.39	-0.23	-0.2	-0.3	0.03	1
* p<0.05; *** p<0.001								

Source: own study / Źródło: opracowanie własne



Source: own study / Źródło: opracowanie własne

Fig. 3. Heatmap for linear Pearson's correlation coefficients between observed traits in 2017 ($r_{critical}$=0.55)
Rys. 3. Mapa ciepła współczynników korelacji liniowej Pearsona pomiędzy cechami obserwowanymi w 2017 roku (r_{kr}=0,55)



Source: own study / Źródło: opracowanie własne

Fig. 4. Heatmap for Spearman's rank correlation coefficients between observed traits in 2017 ($r_{critical}$=0.55)
Rys. 4. Mapa ciepła współczynników korelacji rangowej Spearmana pomiędzy cechami obserwowanymi w 2017 (r_{kr}=0,55)

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