Evaluation of the crop year, soil tillage and fertilisation effect on maize yield using a novel statistical method

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Abstract

Due to climate change, spatial and temporal distribution of precipitation is currently becoming more and more heterogeneous. The examinations were carried out on the Experimental Site of DE-AKIT in 2015-2018 in a complex long-term trial on chernozem soil in non-irrigated conditions. Statistical evaluation: The evaluation and the interaction graph were prepared with R statistical environment and the graphics interface RStudio. Soil tillage, fertiliser and crop year impacts were analysed with a repeated measurement model and its multiple mean value comparison was performed with a Least Significant Difference post hoc test. The highest yield in the average of tillage methods and fertilizer treatments was observed in 2016 (12.04 t/ha), while the lowest yield was recorded during the 2015 production year (7.69 t/ha). There was no statistically justifiable difference among the three tillage methods in 2015. During the 2016 production year, there was no difference between the winter ploughed and subsoiled plots, but significantly lower yields were recorded on strip tillage plots. In 2017, winter ploughing and strip tillage treatments did not differ from each other, but the subsoiling treatment resulted in significantly higher yields. In 2018, all three tillage methods statistically different, the lowest yield was recorded in the case of the strip tillage treatment (8.72 t/ha), while the highest yield was achieved in the subsoiling (9.75 t/ha) treatment.

Keywords repeated measures ANOVA, maize, yield, soil tillage, fertilizer

Introduction

Due to climate change, spatial and temporal distribution of precipitation is currently becoming more and more heterogeneous. Consequently, both internal water and drought might be formed on the fields within a given year. In Hungary, one of the solutions to reduce both drought and inland water could be rippering-based, moisture-saving tillage.

Materials and methods

The examinations were carried out on the Experimental Site of Univerity of Debrecen in 2015-2018 in a complex long-term trial on chernozem soil. The polyfactorial long-term trial has a split-split-plot distribution. The primary plots include the various tillage and irrigation treatments without repetition. On the primary sub-plots maize hybrids are present with a 60-80 thousand/ha plant density, while on the secondary sub-plots, fertilizer treatments are included randomized in four repetitions. In the scope of the study, the effect of tillage and fertilization on the yield of maize was analysed on 80 thousand per hectare non-irrigated in the average of the produced hybrids. Weather data was provided by the Agrometeorological Observatory of the Agrometeorological and Agroecological Monitoring Centre of the Debrecen Training Farm and Landscape Research Institute of the Institutes for Agricultural Research and Educational Farm of the University of Debrecen. The 100 year weather data of Debrecen was provided by the Hungarian Meteorological Service. In terms of precipitation, 2015 was an unfavourable year, as the amount of precipitation was above the multiple year average only after August. In 2016, the high amount of precipitation of June ensured the soil moisture content required for maize to achieve higher yields. In 2017, the precipitation of May and June – which was below the average of multiple years – was an unfavourable factor during the early vegetative phase.

During the production year of 2018, the amount of precipitation during the vegetative phases was below the average of multiple years, while the amount in August supported the growth of grains (Figure 1).

The statistical evaluation and the interaction graph were prepared with R (*R Core Team,* 2016) and the graphics interface RStudio (*RStudio Team,* 2016) with the packages "gplots" (*Warnes et. al.,* 2015), "car" (*Fox and Weisberg,* 2011) and "agricolae" (*de Mendiburu,* 2016).

For the analysis of the involved years, a repeated measurement model was utilized, as it is a distribution-independent method, which handles the effect of the production year as a random treatment. The repeated measurement model created for the analysis of the effects of tillage and fertilization on yield was set up based on the example of Huzsvai and Balogh (2015). The code of the repeated measurement model in R

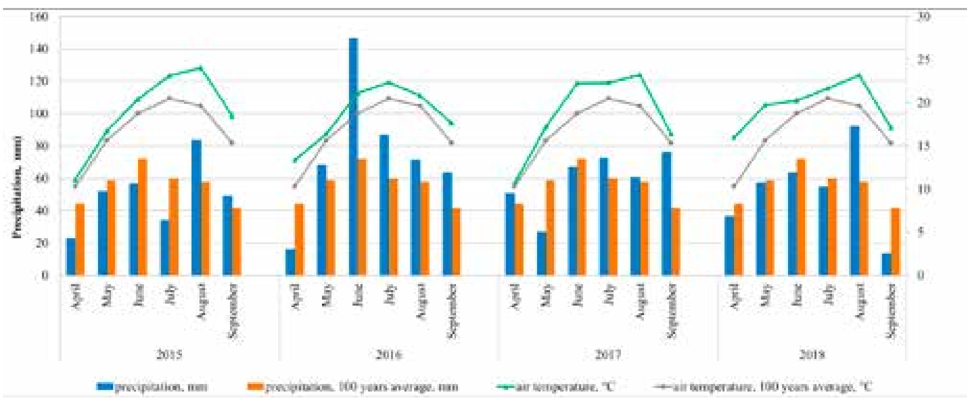

Figure 1: Monthly mean temperature and total precipitation of the analysed years

statistical environment: model< -aov(yield~soil_tillage*fertilizer*year+Error(parcell_id/year), data=database)
summary(model)
Comparison of the mean yield values was carried out by means of least significant difference
post hoc test (*Huzsvai,* 2013):
df=df.residual(modell$“hiba:hiba”)
mse=deviance(modell$“hiba:hiba”)/df
LSD < -with(adatbázis, LSD.test(yield, significant_factor, df, mse, console = T))

Results and discussion

In the average of the examined years and nutrient doses, there was no statistically verifiable different between strip tillage (9.08 t/ha) and either winter ploughing (9.43 t/ha) or subsoiling (9.75 t/ha) tillage treatments.
All three nutrient levels were statistically different from each other, on the control plots 6.25 t/ha yield was measured, while on the 80 kg N/ha+PK treated plots 10.37 t/ha; the yield was 11.64 t/ha on the plots treated with 160 kg N/ha.
As for the average of the analysed years, control plots showed the lowest yield values in all three tillage treatments, which do not have a statistically verifiable difference amongst each other. There was no difference between the winter ploughed (10.77 t/ha), and sub-soiled (10.58 t/ha) 80 kg N/ha treated plots. Strip-tillaged, 80kg N/ha treated plots were behind them (9.76 t/ha). The highest statistically verifiable yield was 12.47 t/ha on the 160 kg N/ha treated,
sub-soiled plots.
Each year was statistically different from each other, the lowest yield was in 2015 (7.69 t/ha), while it was 8.74 t/ha in 2017, and 9.2 t/ha in 2018. In the average of tillage methods and fertilizer doses, the highest yield was 12.04 t/ha in 2016.
There was no statistically justifiable difference among the three tillage methods in 2015. During the 2016 production year, there was no difference between the winter ploughed and subsoiled plots, but significantly lower yields were recorded on strip tillage plots. In 2017, winter ploughing and strip tillage treatments did not differ from each other, but the subsoiling treatment resulted in significantly higher yields. In 2018, all three tillage methods statistically different, the lowest yield was recorded in the case of the strip tillage treatment (8.72 t/ha), while the highest yield was achieved in the subsoiling (9.75 t/ha) treatment (Figure 2).
In terms of the analysed years, the control plots did not differ from each other in a statistically verifiable manner. In 2015, yield of the control plots (5.48 t/ha) was below the yield of the fertilized plots (8.88, 8.71 t/ha); there was no statistically verifiable difference between the fertilizer doses. In 2016, all three fertilizer treatments were different from each other. The highest statistically verifiable yield of the analysed years (14.34 t/ha) was measured in the case of the 160 kg N/ha fertilizer treatment. The second highest statistically verifiable yield of the analysed years was recorded in the case of the 80 kg N/ha+PK fertilizer treatment. In 2017, increase of fertilizer levels improved yield amounts again: yield of the control plots: 5.27 t/ha; 80 kg N/ha+PK plots 9.36 t/ha; 160 kg N/ha plots: 11.59 t/ha. In 2018, yield of maize was 5.57 t/ha on the control plots; 10.11 t/ha on the 80 kg N/ha+PK dose plots and 111.91 t/ha on the 60 kg N/ha+PK treated plots.

Acknowledgement
The field trial and the analyses is supported by KITE cPlc. The research is supported by the project “Establishing a scale-independent complex precision consultancy system (GINOP-2.2.1-15-2016-00001)” The publication is supported by the EFOP-3.6.3-VEKOP-16-2017-00008 project. The project is co-financed by the European Union and the European Social Fund. The research was financed by the Higher Education Institutional Excellence Programme (20428-3/2018/FEKUTSTRAT) of the Ministry of Human Capacities in Hungary, within the framework of the 4. thematic programme of the University of Debrecen.

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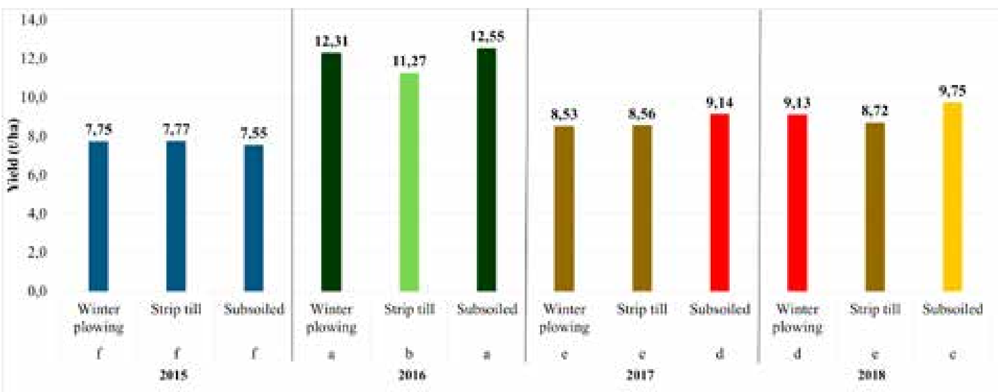

Figure 2: Average yields of different tillage methods during the analysed years