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RESPONSE OF MAIZE YIELD TO VARIATION IN RAINFALL AND AVERAGE TEMPERATURE IN CENTRAL PART OF OLTENIA

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ABSTRACT

Maize yield is highly influenced by environmental factors, especially by increasing average temperature and the uneven distribution of rainfall, in the Oltenia area. Our study evaluated the relationship between maize yield and two climatic factors, namely rainfall and average temperature, using correlation analysis and linear regression method. The experiments with 20 Romanian maize hybrids were placed at Agricultural Research and Development Station Şimnic, during four years (2015-2018). The results show significant impact of average temperature and rainfall on maize yield in this region. The average temperatures during grain-filling period, that correlated strongly negative with the yield (r = -0.973*) and the rainfall during sowing to anthesis period, that correlated strongly positive with the yield (r = 0.966*), were dominant climatic factors which explained of 94.6% and 93.3% respectively, of inter-annual variability of maize yield. Understanding the challenges associated with variation in rainfall and average temperature at specific phenological stages in maize is essential for efficient management of crop production in each area.

Keywords: maize yield, average temperature, correlation, rainfall, phenological phenophases.

INTRODUCTION

In Romania, maize was produced on 2405 thousand hectares with the production of 14326 thousand tons, and average yield of 5.9 tons/ha (FAO, 2017).

Maize (*Zea mays* L.) is a species that needs much water, but due to the low transpiration coefficient (230-440), to the highly developed root system and the possibility of reducing the transpiration surface by twisting the leaves, is considered a drought-resistant plant. However, it is sensitive to water insufficiency in the flowering and grain-filling phenophases. It is considered that the interval from tasseling to end of grain filling is the critical phenophase of maize for water, which lasts about 50 days and overlaps with July and August. For maize, summer rainfall has a decisive influence on yield, and their uniform distribution is more important than the total rainfall. Between the annual quantity of rainfall and maize yield there is a positive correlation, of great importance are the rains from May, June and July. The high rains in September do not contribute to increased yield, being even harmful by prolonging the growing season, but relatively dry weather in October influences the quality of maize and provides good conditions for harvesting and conditioning the yield (Ștefan, 2004).

For the conditions in Romania, the minimum quantity of rainfall for the whole growing season is 250-300 mm, and the optimum between 300-380 mm with the following monthly distribution: 60-80 mm in May, 100-120 mm in June, 100-120 mm in July, and 40-60 mm in August (Salontai and Muntean, 1982).

The extremely high variation, in both the total quantity of rainfall from one year to the next, and their distribution during the year, determine, in some years, important water deficits during crop growing, while in other years excess moisture is recorded. The climate changes over the last few years have accentuated these extreme variations, with severe consequences on agricultural production (Săulescu et al., 2006).

However, it should be possible to adapt to future climates by breeding better genotypes

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(Özdogan, 2011) and changing crop management practices (Xiao et al., 2008).

According to Butts-Wilmsmeyer et al. (2019) water availability during the two critical growth stages of flowering and grain filling is largely responsible for grain yield. Crop yield is primarily determined by a combination of temperature and rainfall because temperatures have to be in the range for plant growth and rainfall has to supply crop water requirements for a given environment. Barron et al. (2003) concluded that water deficit during the flowering phenophase resulted in 75% decrease of maize grain yield.

Many studies have examined climate effects on maize yield in different regions. Understanding climate effects on crop yield has been a continuous endeavour aiming at improving farming technology and management strategy, minimizing negative climate effects, and maximizing positive climate effects on yield (Hu and Buyanovsky, 2003).

Therefore, this study aimed to assess the relationship between climatic factors and maize yield, with reference to rainfall and average temperature recorded in the central part of Oltenia.

MATERIAL AND METHODS

Twenty Romanian maize hybrids were studied for yielding performance under different environmental conditions, during the period 2015-2018. Meteorological data on rainfall and average temperature were obtained from Meteorological Station Şimnic, Craiova. The experiments were placed under rain-fed conditions at Agricultural Research and Development Station Şimnic, and organized in a randomised block design with three replications.

Sowing was made on 16.04.2015; 22.04.2016; 10.04.2017 and 24.04.2018 respectively. The crop sown in the previous year was wheat.

Ploughing was done in autumn. In spring germination bed was prepared with the disc and the combiner.

Fertilization was done with 250 kg/ha (NPK 20:20:0) complex fertilizers before sowing and in vegetation (phase 8 - 10 leaves) with ammonium nitrate 250 kg/ha.

The herbicides used were Dual Gold 960 - 1.5 l/ha immediately after sowing and Equip 1.5 l/ha + Buctril 1.0 l/ha in vegetation, (phase 6 - 8 leaves).

Two mechanical and two manuals weeding were applied.

Influence of rainfall and average temperature on maize grain yield was analysed according to: date of sowing, emergence date, anthesis date, silking date, physiological maturity date, and harvest date.

The grain-filling period was calculated, for each hybrid, as a number of days from silking to physiological maturity (considering that within a few hours of the emergence of silks, pollination occurred and the embryo was formed).

Date of emergence was noted when 75% of the coleoptiles were visible at soil surface.

Days to anthesis and silking were calculated as the number of days from sowing to when 75% of plants, in each plot, had shed pollen or had emerged silks, respectively.

Anthesis - silking interval was calculated as the number of days from anthesis to silking date for each hybrid.

Date of physiological maturity was noted when the black layer was visible at the base of the grain and grain moisture was about 32-35% (Burzo et al., 1999)

Yield per hectare was calculated to 15.5% moisture.

Data were analysed using statistical software Excel 2010, statistically processed by the linear regression method and correlation analysis (Săulescu and Săulescu, 1967; Opariuc-Dan, 2011).

RESULTS AND DISCUSSION

Weather data during growth period of maize in the interval 2015-2018

Years of experimentation were different from a climatic point of view, both in terms of the total rainfall during the maize growing season, their monthly distribution, and monthly average temperatures (Table 1).

Table 1. Quantity, rainfall distribution (mm) and monthly average temperatures (°C) during maize growing season at ARDS Şimnic, during 2015-2018

Item	Year	April	May	June	July	August	Sum/average 1.04 - 31.08 (%)
Rainfall (mm)	2015	36	72	63	24	64	259.0 (79%)
	2016	34	87	106	23	37	287.0 (88%)
	2017	63	71	24	108	7	273.0 (83%)
	2018	11	51	141	135	28	366.0 (112%)
	Average	36	70.2	83.5	72.5	34	296.2 (90%)
	Multi-annual average (last 21 years)	53.1	71.7	73.6	82.2	47	327.6 (100%)
Temperature ^{0}C	2015	11.6	18.2	20.8	25.0	23.8	19.9 (102%)
	2016	14.9	16.1	22.4	24.2	23.4	20.2 (104%)
	2017	11.3	17.2	23.2	24.4	25.2	20.3 (104%)
	2018	16.3	19.7	22.1	23.0	24.6	21.1 (108%)
	Average	13.6	17.8	22.1	24.2	24.3	20.4 (105%)
	Multi-annual average (last 21 years)	12.2	17.5	21.5	23.8	22.5	19.5 (100%)

The sum of rainfall registered during the maize growing season, in the years of experimentation, was below the multi-annual average, accounting for 90% of this. In 2015, 2017 and 2016 rainfall represented only 79%, 83% and 88%, respectively of the multi-annual average of the area (327.6 mm), suggesting that, the quantity of water in these years was insufficient to cover the maize water requirement. In 2018, sum of rainfall exceeded by 12% the multi-annual average, suggesting favourable climatic conditions for maize crop.

Monthly average temperatures during the years of experimentation were higher compared to the multi-annual average, with 2% in 2015, with 4% in 2016 and 2017, and with 8% in 2018, reflecting the warming trend during experimentation period.

Effect of rainfall and average temperature on maize yield

The average yields of the 20 maize hybrids, in the four years of experimentation, were reported at the total quantity of rainfall in the interval 1.04 - 31.08 (Figure 1).

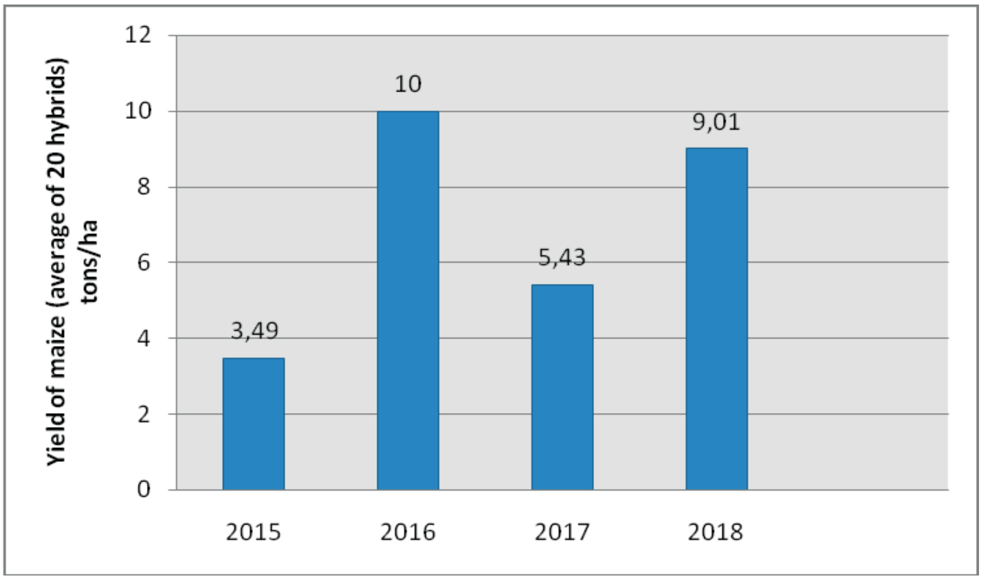


Figure 1. The average grain yields t/ha obtained by the 20 maize hybrids during the study period

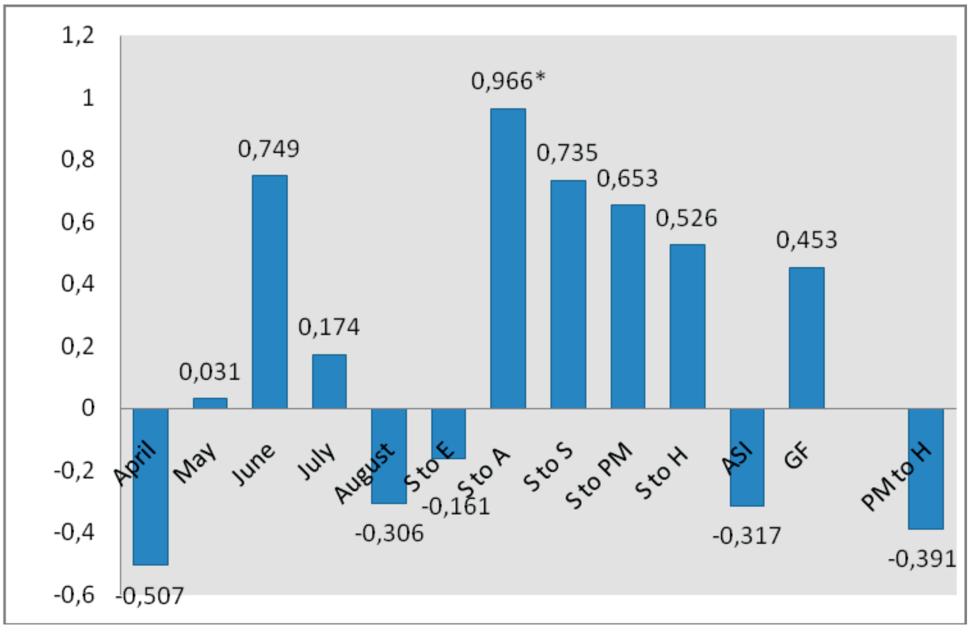
In 2015 with drought in April, June and July, the average yield was 3.49 t/ha, in 2016 with a deficit of rainfall in April, July and August - average yield was 10.0 t/ha, and in 2017 with a rainfall deficit in June and August, the average yield was 5.43 t/ha. The year 2018 with a surplus of rainfall in June and July and deficit in April, May and August, resulted in an average yield of 9.01 t/ha.

Although rainfall in 2016 was lower than in 2018, the more even distribution during the growing period, which determined an yield increase of 1000 kg/ha, was more important in defining the yield of maize hybrids than the total quantity of rainfall.

The very high value of the variation coefficient for average yields/ha (41.4%) showed that during the experimentation period (2015-2018), climate changes from year to year or during the same year from month to month, caused a strong fluctuation of maize yield.

Relationship between rainfall and maize yield

Relationships between the quantity of rainfall fallen in a certain calendar period (month) or maize growth phenophase and maize yield are shown by the correlation coefficients (Figure 2).



S to E = sowing to emergence; S to A = sowing to anthesis; S to S = sowing to silking; S to PM = sowing to physiological maturity; S to H = sowing to harvesting; ASI = interval from anthesis to silking; GF = grain-filling; PM to H = physiological maturity to harvesting; *significant for p = 0.05 (GL = 2)

Figure 2. Correlation coefficients between grain yield and total rainfall at specific phenological phenophases or monthly in 20 maize hybrids, at ARDS Şimnic

The results obtained showed that only rainfall from sowing to anthesis period was there a significant ($p = 0.05$) strong positive relationship with maize yield ($r = 0.966$*).

Rainfall during May ($r = 0.031$) and July ($r = 0.174$) have insignificantly influenced maize yield, and rainfall during grain-filling period had weakly influenced ($r = 0.453$).

A favourable influence had the rainfall in June ($r = 0.749$) and those from sowing to silking ($r = 0.735$) which correlated strongly positive (but non-significant) with maize yield. The moderate correlations, but non-significant existed between the rainfall from sowing to physiological maturity ($r = 0.653$), sowing to harvesting ($r = 0.526$) and maize yield.

On the contrary, Şerban (2010) for ARDS Teleorman (Romania) and Milošević et al. (2015) for Vojvodina (Serbia) reported that rainfall during July and August significantly positive influenced maize yield and the rainfall in other months had an insignificant influence.

A negative influence was noticed for the rainfall during April (r = -0.507) which correlated non-significantly, but moderate and negatively with maize yield. For the rainfall in August (r = 0.306), and those from sowing to emergence (r = -0.161), in anthesis-silking interval (r = -0,317) and from physiological maturity to harvesting period (r = -0.391), the correlations was non-significant, weak and negative. Therefore, the quantity and distribution of rainfall at these phenophases was detrimental to maize yield.

Numerous researchers believe that excessive moisture during the sowing period, which would inhibit soil aeration and increase the diseases pressure interfering with germination and seed growth, results in reduction of maize yield (Huang et al., 2015). According to Hu and Buyanovsky (2003), the sowing time depends very much on weather conditions. Excessive or deficient moisture delays sowing affecting maize yield by shortening the growth season or exposing its ripening to deep frost damage. Therefore, even though management decides the sowing date, the weather condition during the sowing window deciphers the date and, more important, determines the outcome of the sowing. Guarienti et al. (2005) reported that the high rainfall after wheat physiological maturity influences negatively the grain yield due to increased severity of disease and enzyme activity.

Equations and linear regression coefficients indicated that yield increased or decreased with increasing rainfall (Table 2). For every increase of 1 mm of rainfall from sowing to anthesis, maize yield increased by 138 kg/ha and for every increase of 1 mm of rainfall during June and those from sowing to silking, maize yield increased by 44 and 115 kg/ha, respectively.

Table 2. Regression result between grain yield and rainfall at specific phenological phenophases or monthly of 20 maize hybrids

Item	Regression equation	R^2
April	Y = -0.072x + 9.597	0.257
May	Y = 0.006x + 6.527	0.001
June	Y = 0.044x + 3.234	0.561
July	Y = 0.009x + 6.316	0.030
August	Y = -0.039x + 8.322	0.093
Sowing to emergence	Y = -0.020x + 7.646	0.026
Sowing to anthesis	Y = 0.138x – 17.84	0.933
Sowing to silking	Y = 0.115x – 14.81	0.540
Sowing to physiological maturity	Y = 0.033x - 1.607	0.425
Sowing to harvesting	Y = 0.022x + 0.254	0.276
Anthesis - silking interval	Y = -0.047x + 7.507	0.010
Grain - filling	Y = 0.025x + 5.127	0.204
Physiological maturity to harvesting	Y = - 0.033x + 8.421	0.153

The values of the determination coefficients (R^2) for rainfall varied between 0.1 and 93.3%, indicating that up to 93.3% of variation in maize yield could be explained by rainfall variability in a certain month or the phenophase growth, and the remaining 6.7% was largely due to other factors (genetic, climatic, fertility of the soils, crop management etc.).

Rainfall from the sowing to anthesis period had a stronger influence on maize yield than the rainfall during the grain-filling period. On the contrary, Mitu and Rînchiță (2006), in a study conducted at ARDS Teleorman with 14 Romanian maize hybrids, reported that the predominance of rainfall during vegetative growth of maize influenced the yield increase by 26% and those during reproductive growth, by 74%.

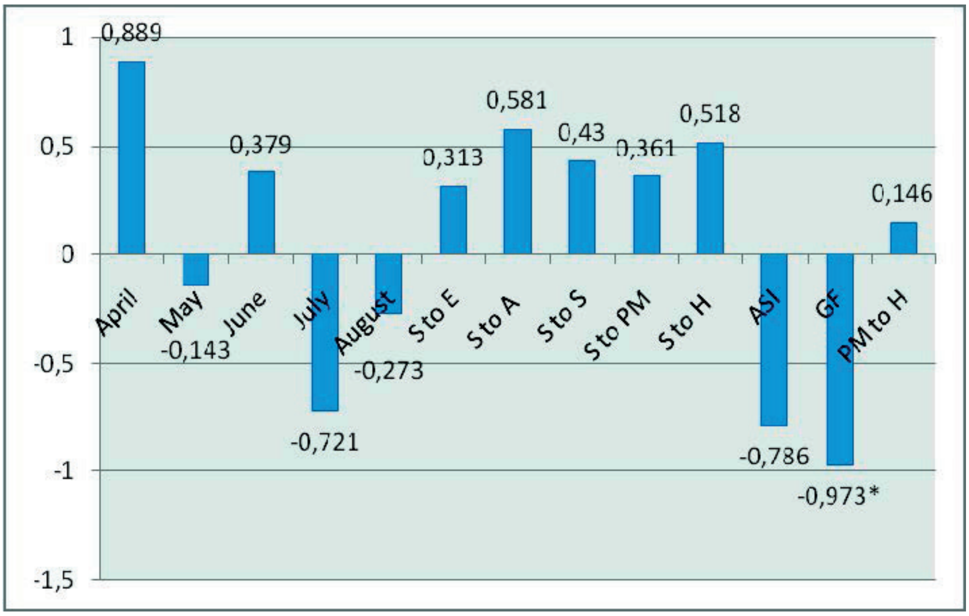
Relationship between average temperature and maize yield

Regarding the influence of average temperatures, only average temperatures during grain-filling period had a significant (p = 0.05) strong negative relationship with maize yield (r = -0.973*) (Figure 3). Non-significant (p = 0.05), but strong negative correlations were obtained for average temperatures during July (r = -0.721) and those in anthesis-silking interval (r = -0.786). Therefore, mean temperature in these phenophases was detrimental to maize grain yield.

A favourable influence was noticed for the average temperatures during April and those from sowing to anthesis which correlated non-significant, but strong positive (r = 0.889) or moderate positive (r = 0.581) with maize yield.

In all other periods the correlations were weak and non-significant.

Hatfield (2016) showed that exposure to higher temperatures during the grain-filling period, shortened the grain-filling period by increasing the rate of senescence, reducing grain yield in three maize hybrids.



S to E = sowing to emergence; S to A = sowing to anthesis; S to S = sowing to silking; S to PM = sowing to physiological maturity; S to H = sowing to harvesting; ASI = interval from anthesis to silking; GF = grain-filling; PM to H = physiological maturity to harvesting; *significant for p = 0.05 (GL = 2)

Figure 3. Correlation coefficients between grain yield and average temperature at specific phenological phenophases or monthly of 20 maize hybrids, at ARDS Şimnic (2015-2018)

Linear regressions showed that for every increase of 1°C of average temperature during the grain-filling period, maize yield decreased by 3274 kg/ha and for every increase of 1°C of average temperature during July and the anthesis-silking interval, maize yield decreased by 2610 kg/ha and 1461 kg/ha, respectively (Table 3). For every increase of 1°C of average temperature during April, maize yield increased by 1098 kg/ha.

Shim et al. (2017) showed a significantly negative correlation between grain yield and average temperatures during the grain-filling in both cultivars of maize studied (r = -0.627** and r = -0.629**).

The values of the coefficients of determination (R^2) for average temperatures varied between 2.0% and 94.6%, indicating that this climatic factor had a stronger influence on maize yield than rainfall.

Table 3. Regression result between grain yield and average temperature at specific phenological phenophases or monthly of 20 maize hybrids

Item	Regression equation	R^2
April	Y = 1.098x – 7.918	0.789
May	Y = -0.286x + 12.08	0.020
June	Y = 1.153x – 18.56	0.143
July	Y = -0.2610x +70.05	0.519
August	Y = -1.055x + 32.58	0.074
Sowing to emergence	Y = 0.241x + 3.361	0.098
Sowing to anthesis	Y = 1.557x – 22.73	0.337
Sowing to silking	Y = 1.143x – 14.81	0.183
Sowing to physiological maturity	Y = 1.442x – 23.29	0.129
Sowing to harvesting	Y = 3.231x – 61.7	0.268
Anthesis - silking interval	Y = -1.461x + 41.56	0.617
Grain - filling	Y = -3.274x + 87.83	0.946
Physiological maturity to harvesting	Y = 0.323x – 0.346	0.020

Similar results were obtained by Badu-Apraku and Fakorede (2006), who reported significant positive correlations between grain yield and total rainfall from sowing to anthesis (r = 0.761**), to silking (r = 0.767**) and grain filling stages (r = 0.824**) for 25 early-maturing maize varieties. Oke (2016) reported that for grain-filling stage and for whole growth cycle, yield of maize was positively correlated with total rainfall and negatively correlated with average temperature.

To minimize the negative impacts of climate changes and to take advantage of positive impacts in southern Romania, Cuculeanu et al. (1999) suggested that the dominant strategy should be to use the following adaptation options in maize: the application of irrigation, use of longer maturing hybrids, sowing in the last 10 days of April, use of a plant density of 5 plants/m^2, and the increase of nitrogen levels up to 120-160 kg/ha.

CONCLUSIONS

Based on the results obtained, it can be concluded that the rainfall and average temperatures during the four years of research, were very different, especially due to the quantity and uneven distribution of rainfall from one year to another year and from one phenophase to another, and this variation affected the growth and maize yield in the study area.

Therefore, assessment of maize response to agro-climatic factors in each crop area, may be the basis for providing farmers with adequate information, so that they to properly plan the specific production management strategies.

In this study we noticed that both studied climatic factors (average temperature and rainfall) had a greate influence on the maize yield.

The rainfall from sowing to anthesis period, that correlated strongly positive with the yield (r = 0.966*), and the average temperatures during grain-filling period, that correlated strongly negative (r = -0.973*) with the yield, were dominant climatic factors which explained of 93.3% and 94.6% respectively, of inter-annual variability of maize yield.

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