# RESEARCH ON THE EXPLOITATION WATER AND CLIMATIC FACTORS BY MAIZE HYBRIDS OF DIFFERENT FAO GROUPS AND THEIR ADAPTATION TO CLIMATE CHANGE

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**Abstract**

The researches and observations proposed by the presented paper aim to identify those corn hybrids that make superior use of rainwater and that lend themselves to the local climate conditions specific to the south-western area of Romania. The research was carried out by testing 18 maize hybrids from different FAO maturity groups, from FAO-350 to FAO-500 (6 hybrids from FAO group 350-400, 6 hybrids from FAO group 400-500, 6 hybrids from FAO group 450-500), in 2021 and 2022. Determining the Water use efficiency (WUE) resulted in values between 0.09 – 0.29 $m^3$/kg, thus hybrids that can make superior use of water. Comparing the total volume of precipitation recorded in the period April-September of 2021-2022 with the water consumption (ET) for that period, the appearance of the moisture deficit (550.38 mm in 2021 and 594.51 mm in 2022, respectively), a deficit that has values higher than the multiannual average (506.17 mm) is observed. Precipitation between April and September of 2021-2022 is lower than the sum of the multiannual average, 301.40 mm (2021) and 272.20 mm (2022) respectively compared to 318.70 mm (multiannual average).

**Key words**: climate, water, maize, production

## INTRODUCTION

Globally, climate change issues are frequently researched.

Weather predictions show clear increases in temperatures and implicitly a concomitant increase in evapotranspiration, but also frequent episodes of climatic anomalies, such as droughts that are frequent in the southwestern area of Romania (Cioboată *et al*, 2012).

Recently, a study was published (Șumuleac *et al*, 2020) on the evolution of the weather in Romania, in the Banat Chamber with data for a period of 122 years for temperature, and for precipitation with data for 146 years. The study showed that the average temperature increased throughout the agricultural year, but also during the vegetation period, and precipitation tends to decrease values, especially during the vegetation period (Șumuleac *et al*, 2020).

Crop productivity fluctuates from one year to another, being significantly influenced by the variability of climatic conditions and especially by extreme climatic events (Nițu Alina *et al*, 2010).

In case of an increase in average temperatures by $2^0$C, the water requirement for irrigation in maize will be 61% above the current requirement, and in the case of a $5^0$C increase in temperature, the water requirement will be 74% above the current requirement (Nițu Alina *et al*, 2023).

Of all-natural resources, water is the most limiting natural resource for the agricultural system, however, it is well known that the need for water varies depending on the species, but it must also be known how it varies depending on the variety and hybrid.

Evapotranspiration, grain yield, biomass, water use efficiency, and crop yield index are all affected by soil water content during the growing season.

The scientific interest in research on the efficiency of water use in crops has focused on the evaluation of new irrigation techniques but also on the genetic variation of water use efficiency in rootstocks or varieties (Amitav Bhattacharya, 2019).

One way to interpret climate data over time, and the correlations between them, is to use climate charts. A prominent example is the Walter-Lieth climate diagram (Walter H. *et al*, 1967). One advantage of the Walter-Lieth climate chart is that it graphically highlights wet or arid periods during the year. This is a simple, but very distinguished and useful classification method for estimating the

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growing conditions of vegetation at first glance (Zepner L. *et al*, 2020).

## MATERIAL AND METHOD

The research and observations were carried out based on data recorded in the central area of the south-west region of Romania, at the Agricultural Research and Development Station Caracal (ARDS-Caracal), part of the University of Craiova. ARDS-Caracal (latitude - $44^0$6' N, longitude - $24^0$21'25'' E) it is located in a plain area (altitude 91 m), on a soil with good fertility (argic chernozem), and the climate is temperate continental, with particularly hot summers and mild winters in general.

The studied material was represented by a number of 18 maize hybrids from different FAO groups, from FAO-350 to FAO-500. Those hybrids that have been tested for 2 consecutive years (2021 and 2022) in the independent testing and analysis network of the Romanian Corn Producers Association were analyzed (APPR).

The weather data recorded at the Caracal weather station, data for the multiannual average and data for the years 2021 and 2022 were used. And for the interpretation of climatic conditions, Walter-Lieth climate diagrams were made. This diagram provides a generalized representation of temperature and precipitation values for the time of year. The temperature and precipitation scales are fixed in the chart in a ratio of 1:2 and 1:3, making it easy to compare different periods.

With the help of climatic data, water consumption (evapotranspiration - ET) was indirectly determined according to the modified Blaney-Criddle method (Popescu et al. 1994), A method that uses the direct link between evapotranspiration and the average monthly temperature, on the one hand, and the monthly percentage of the annual duration of daylight hours, on the other hand, using a seasonal correction coefficient specific to different agricultural crops. The calculation formula used is:

$ET_o = K\,p \cdot (0.457 \cdot T_{mean} + 8.13)$ mm $zi^{-1}$

where: K = empirical coefficient for evapotranspiration according to plant and type of climate; p = percentage of daylight hours in the year; t = average monthly temperature in $^0$C, (values for K and p were obtained from the literature).

With the help of the production data obtained, the water use efficiency (WUE) in the two years of analysis was determined.

WUE represents the ratio between the amount of total water consumed (ET) and the production obtained, $m^3$ of water/kg production per ha. Low WUE values indicate a higher water recovery. The better use of water is due, on the one hand, to a lower total water consumption, as a result of lower evaporative losses, and on the other hand, to an increased production per hectare as a result of the overall environmental conditions and the adaptability of hybrids.

## RESULTS AND DISCUSSIONS

The investigated maize hybrids were divided for the analysis of production into 3 maturity groups, 6 hybrids in each group (Table 1.).

From the comparative analysis of the FAO 450-500 group, we can see that the average of the group had a production in 2021 of 8060.33 kg/ha, and in 2022 the production was 4354.83 kg/ha (*Table 1*). It is found that the hybrids Sy Carioca, Persic and KWS Advisio exceeded the average of the group in the reference years (2021 and 2022), which means a stability of these hybrids and their recommendation for intensive cultivation. The other hybrids analyzed achieved values between 89.72 and 99.24% of the average maturity in 2021 and respectively between 71.00 and 90.61% of the average maturity in 2022.

From the analysis of the FAO 400-450 group, we can see that the average of the group had a production in 2021 of 8092.33 kg/ha, and in 2022 the production was 4509.50 kg/ha (Table 1). It is noted that the performing hybrids were, in 2021, LG 31415 (9006 kg/ha) and Sy Minerva (8714 kg/ha) respectively and in 2022 KWS Donjuan (4952 kg/ha) and KWS Inteligens (4521 kg/ha). With one exception (KWS Inteligens in 2021), the other hybrids recorded a percentage of the average maturity value of over 95% in both reference years (2021-2022).

In the third group FAO 350-400 we can see that the average of the group had a production in 2021 of 8142.67 kg/ha and respectively 4300.00 kg/ha in 2022. The most productive hybrids in both reference periods were: KWS Kashmir (8380 kg/ha in 2021 and 4529 kg/ha in 2022), DM 3330 (8832 kg/ha in 2021 and 4759 kg/ha in 2022) and Sy Premo (8524 kg/ha in 2021 and 4535 kg/ha in 2022). With values close to % of the average maturity are the hybrids Ajovan (99.01% in 2021 and 92.26% in 2022) and RGT Texero (93.08% in 2021 and 97.37% in 2022).

Examining the climatic temperature and precipitation data (Table 2), for the years 2021, 2022 and the multiannual average (My.a), the following is found:

- the average air temperature values are increasing between May and August, for the years 2021, 2022 compared to the multiannual average.

Table 1

**Results regarding production per hectar, kh/ha at H=15% humidity**

| Group | Hybrid | | Production (kg/ha) at U=15% | | % of average maturity | |
|---|---|---|---|---|---|---|
| | | | 2021 | 2022 | 2021 | 2022 |
| FAO 450 - 500 | **FAO** | **Average** | **8060,33** | **4354,83** | **100** | **100** |
| | 460 | FELIX | 7999 | 3946 | 99.24 | 90.61 |
| | 460 | SY CARIOCA | 8668 | 4643 | 107.54 | 106.62 |
| | 460 | PERSIC | 8602 | 5010 | 106.72 | 115.04 |
| | 470 | F423 | 6991 | 3679 | 86.73 | 84.48 |
| | 480 | KWS ADVISIO | 8870 | 5759 | 110.05 | 132.24 |
| | 490 | SY ANDROMEDA | 7232 | 3092 | 89.72 | 71.00 |
| FAO 400 - 450 | **FAO** | **Average** | **8092,33** | **4509,5** | **100** | **100** |
| | 400 | KWS DONJUAN | 8070 | 4952 | 99,72 | 109.81 |
| | 410 | LG 31.415 | 9006 | 4420 | 111,29 | 98.02 |
| | 420 | KWS INTELIGENS | 6786 | 4521 | 83,86 | 100.26 |
| | 420 | RGT URBANIXX | 7910 | 4294 | 97,75 | 95.22 |
| | 430 | MAS 440D | 8068 | 4436 | 99,70 | 98.37 |
| | 440 | SY MINERVA | 8714 | 4434 | 107.68 | 98.33 |
| FAO 350 – 400 | **FAO** | **Average** | **8142,66** | **4300** | **100** | **100** |
| | 360 | AJOVAN | 8062 | 3967 | 99.01 | 92.26 |
| | 360 | RGT TEXERO | 7579 | 4187 | 93.08 | 97.37 |
| | 370 | KWS KASHMIR | 8380 | 4529 | 102.91 | 105.33 |
| | 380 | DM3330 | 8832 | 4759 | 108.47 | 110.67 |
| | 380 | LG 31.390 | 7479 | 3823 | 91.85 | 88.91 |
| | 390 | SY PREMO | 8524 | 4535 | 104.68 | 105.47 |

Table 2

**Weather data**

| Year / month | | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Average Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature (°C) | 2021 | 1,5 | 3,2 | 5,0 | 9,7 | 17,4 | 21,4 | 25,6 | 24,8 | 18,4 | 10,18 | 7,32 | 2,57 | 12,25 |
| | 2022 | 1,96 | 4,13 | 4,48 | 11,11 | 18,17 | 23,03 | 25,42 | 24,8 | 18 | 13,69 | 2,62 | 1,7 | 13,37 |
| | My.a | -3,0 | -0,6 | 4,8 | 11,2 | 16,6 | 20,5 | 22,7 | 21,9 | 17,6 | 11,3 | 4,9 | -0,5 | 10.6 |
| Precipitation (mm) | 2021 | 98,0 | 29,6 | 92,4 | 32,6 | 55,6 | 103,2 | 92,0 | 13,4 | 4,6 | 101,4 | 28,0 | 60,8 | 711,6 |
| | 2022 | 19,2 | 4,8 | 13,2 | 77,8 | 44,6 | 14,2 | 30 | 50,2 | 55,4 | 15 | 34,8 | 10,8 | 370 |
| | My.a | 33,3 | 30,4 | 34,9 | 43,6 | 64,9 | 67,0 | 52,9 | 50,7 | 39,6 | 40,4 | 40,3 | 39,4 | 537.4 |

- In the months of corn vegetation (2021, 2022) average temperatures were recorded even 3 degrees above the multiannual average.

- in 2021, 2022, precipitation is spatio-temporally fluctuating and unevenly distributed, thus values of 32.6 mm (April 2021), 77.8 mm (April 2022), 14.2 mm (June 2022), 103.2 mm (June 2021), 92.0 mm (July 2021), 30.0 mm (July 2022) and 13.4 mm (August 2021), 50.2 mm (August 2022) were recorded.

- the total amounts of precipitation between April and September of the years 2021-2022 are lower than the sum of the multiannual average (301.40 mm-2021 and 272.20 mm-2022 respectively compared to 318.70 mm-My.a).

- the rainfall related to the multiannual average does not show monthly extremes.

Climatic factors have a major influence on the vegetation of cultivated plants, influencing their growth and development process.

By transposing these climatic data into Walter-Lieth charts (figures 1,2,3) it is possible to identify the periods of the year that can pose problems in the development of vegetation and fruiting of corn, as follows:

- From the study of multiannual data with the help of the climate diagram (Figure 1), it can be seen that the January-June and October-December intervals are wet periods, and the July-September interval presents a risk of drought.

- The climate chart for 2021 (Figure 2) indicates a suitable climate for corn, with a wet period from January to early August, and drought set in in August and September.

- From the examination of the climate chart for 2022 (Figure 3), there is a dry period in February and the onset of drought in June, July and August, which also influenced the low level of production this year.

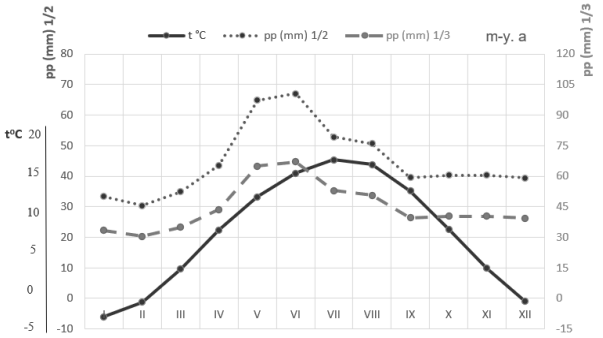


Figure 1. **Multiannual average climate diagram**

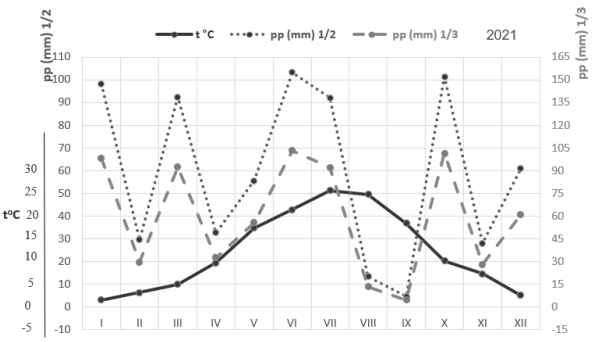


Figure 2. **Climate diagram of 2021**

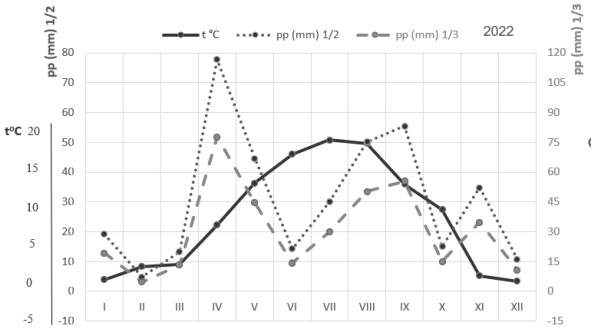


Figure 3. **Climate diagram of 2021**

From the determination of the water consumption (ET) for 2021, (table 3) it is found:

Tabelul 3

**Water consumption in 2021**

| *Month* | *Average temp. ($^{0}C$)* | *Precipitation (mm)* | *ET Blaney-Criddle (mm)* | *Deficit (mm/ha)* |
|---|---|---|---|---|
| April | 9,7 | 32,6 | 96,80 | 64,20 |
| May | 17,4 | 55,6 | 140,73 | 85,13 |
| June | 21,4 | 103,2 | 159,24 | 56,04 |
| July | 25,6 | 92,0 | 178,32 | 86,32 |
| August | 24,8 | 13,4 | 158,74 | 145,34 |
| September | 18,4 | 4,6 | 117,95 | 113,35 |
| Total | 19,6 | 301,40 | 851,78 | 550,38 |
| My.a | 18,42 | 318,70 | 824,87 | 506,17 |

- the indirectly estimated water consumption has increasing values starting with April and including July (from 96.80 mm to 178.32 mm), remaining high in the following months (158.74 mm in August and 117.95 mm in September); The total period ET is 851.78 mm.

- comparing the total volume of precipitation recorded in the period April-September (301.40 mm) with the ET for that period (851.78 mm), a total moisture deficit of the period of 550.38 mm is found.

Analyzing the ET data for 2022 (Table 4) it can be seen:

- the indirectly estimated water consumption has increased values starting with April and including July (from 101.77 mm to 177.58 mm), remaining high in the following months (161.05

mm in August and 116.64 mm in September); The total ET of the period is 866.71 mm.

- comparing the total volume of precipitation recorded in the April-September period (272.20 mm) with the ET for that period (866.71 mm) there is a total moisture deficit of 594.51 mm for the period.

The values of the moisture deficit are variable and with an increasing trend throughout the analysis period and are due to the combined action of climatic factors with the needs of the plant.

Tabelul 4

**Water consumption in 2022**

| *Month* | *Average temp. ($^{0C}$)* | *Precipitation (mm)* | *ET Blaney-Criddle (mm)* | *Deficit (mm/ha)* |
|---|---|---|---|---|
| April | 11.11 | 77.8 | 101,77 | 23,97 |
| May | 18.17 | 44.6 | 143,81 | 99,21 |
| June | 23.03 | 14.2 | 165,86 | 151,66 |
| July | 25.42 | 30,0 | 177,58 | 147,58 |
| August | 25.42 | 50.2 | 161,05 | 110,85 |
| September | 18,00 | 55.4 | 116,64 | 61,24 |
| Total | 20,19 | 272,20 | 866,71 | 594,51 |
| My.a | 18,42 | 318,70 | 824,87 | 506,17 |

Comparing the total volume of precipitation recorded in the period April-September of 2021-2022 with the ET for that period, the appearance of the moisture deficit (550.38 mm in 2021 and 594.51 mm in 2022, respectively), a deficit that has values higher than the multiannual average (506.17 mm) is observed.

From the point of view of water consumption, they are hybrids with very high potential in optimal humidity conditions, but which have unsatisfactory results if they are no longer ensured, or those optimal conditions no longer exist. The Water Use Efficiency Analysis (WUE) gives us indications on the amount of water consumed by hybrids to achieve one kg of production, thus identifying hybrids that have a high capacity for superior water recovery in irrigated and non-irrigated conditions.

This parameter also helps us to identify hybrids that have stability in terms of water availability and hybrids that are more drought tolerant.

The WUE value must be as small as possible, ideally subunitary, the value of this index being greatly influenced by the hybrid, soil, applied technology, etc.

Analysing the WUE values obtained for the 18 hybrids between 2021 and 2022 (Figure 4), it follows:

1) Comparing the WUE according to the maturity group, we find similar efficiency values for 2021 (on average 0,11 $m^3$/kg), and in 2022 there are values between 0,15-0,28 $m^3$/kg).

2) For cultivation in a non-irrigated regime, hybrids with high yields have been obtained in correlation with the efficiency of using water with the lowest possible value are recommended:

*a)* for the FAO 450-500 group, it stands out,: Sy Carioca (8668 kg/ha with 0,10 $m^3$/kg), Persic (8602 kg/ha with 0,10 $m^3$/kg) and KWS Advisio (8870 kg/ha with 0,10 $m^3$/kg), results in 2021. In 2022, the results were: KWS Advisio (5759 kg/ha with 0,15 $m^3$/kg), Persic (5010 kg/ha with 0,17 $m^3$/kg), Sy Carioca (4643 kg/ha with 0,19 $m^3$/kg).

*b)* for the FAO 400-450 group, it stands out: LG 31415 (9006 kg/ha with 0,09 $m^3$/kg), Sy Minerva (8714 kg/ha with 0,10 $m^3$/kg) and KWS Donjuan (8670 kg/ha with 0,11 $m^3$/kg), results in 2021, and in 2022 there were: KWS Donjuan (4952 kg/ha with 0,18 $m^3$/kg) and Sy Minerva (4434 kg/ha with 0,20 $m^3$/kg).

*c)* for the FAO 350-400 group, it stands out: DM 3330 (8832 kg/ha with 0,10 $m^3$/kg), Sy Premo (8524 kg/ha with 0,10 $m^3$/kg) și KWS Kashmir (8380 kg/ha with 0,10 $m^3$/kg), results recorded in 2021, and in 2022 there were: DM 3330 (4759 kg/ha with 0,18 $m^3$/kg), Sy Premo (4535 kg/ha with 0,19 $m^3$/kg) and KWS Kashmir (4529 kg/ha with 0,19 $m^3$/kg).

3) The lowest WUE values were recorded in the LG 31415 hybrid of the FAO 400-450 group (0,09 $m^3$/kg in 2021) and KWS Advisio from the FAO 450-500 group (0,15 $m^3$/kg in 2022).

4) The highest WUE values were recorded in the KWS Inteligens hybrid of the FAO 400-450 group (0,13 $m^3$/kg in 2021) and Sy Andromeda respectively from the FAO 450-500 group (0,28 $m^3$/kg in 2022).

5) The lowest average values of the WUE were recorded in the FAO 350-400 group (0,10 $m^3$/kg in 2021) and FAO Group 400-450 (0,19 $m^3$/kg in 2022).

Figure 4**. Water Use Efficiency Analysis (WUE) (mc kg$^{-1}$)**

Water use efficiency can be analyzed from several points of view: economic, transport, mode of application, etc., but more specifically, water use efficiency (WUE) refers to the response of crops to the availability of water in the soil. While crops face some degree of stress caused by drought, water use efficiency is improved. In non-irrigated conditions, the distribution of precipitation during the vegetation period is decisive in achieving productions and directly influences the WUE. Water is used better if it is available during critical plant periods. For the years 2021 and 2022, the decisive rainfall in establishing the productions were those recorded during the months of May, June and July (Figure 5).

In the case of maize, the water reserve formed by the accumulation of precipitation in the soil during winter and early spring can ensure the living conditions of maize in the first two months of May-June (Şimon *et al*, 2023).

Figura 5**. Distribution of rainfall in 2021**

## CONCLUSIONS

From the analysis of the average values of the air temperature, it is found to increase by even +3$^0$C, between May and August, for the years 2021, 2022 compared to the multiannual average.

In 2021, 2022, precipitation fluctuates spatio-temporally and unevenly distributed, the total amounts of precipitation in the April-September period of 2021-2022 are lower than the sum of the multiannual average.

From the study of climate data with the help of the Walter-Lieth chart, those wet, dry or dry periods can be observed. And according to the multiannual average, the July-September interval presents a risk of drought, phenomena encountered in 2021 and 2022.

The decisive rainfall in establishing the productions (±) are those recorded during the months of May, June and July.

Hybrids recommended for non-irrigated cultivation, in the South-West area of Romania, are those in which high yields have been obtained in correlation with the efficiency of water use with the lowest possible value (*a, b, c*), described in the paper.

The low WUE values recorded in the FAO 350-400 group in 2021 and in the FAO 400-450 group in 2022, recommend as suitable for cultivation in this area hybrids with FAO up to 450.

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