THE EVOLUTION OF THE TYPE AND MATURITY GROUP OF MAIZE HYBRIDS REGISTERED IN ROMANIA OVER TIME

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Abstract

Maize is the most grown crop in Romania (2.68 million ha in 2020 according to FAO database), this being used widely in human food and in animal feed. The history of hybrid maize in Romania is impressive starting in 1957 when the first foreign double cross hybrids were cultivated. The first double cross hybrids produced nationally were HD 208 and HD 405 registered in 1962 and 1963 respectively, which lead to their widespread use in only 7 years.
The aim of this study was to evaluate how the registration of the new maize hybrids has evolved over time in Romania in term of number and type of hybrid and to see if there is any correlation between the increase of the average annual temperature and the maturity group of these hybrids. The study led to the following main conclusions: the tendency in the last time was a reduction close to 0 of double-cross hybrids registered; there is a clear direction towards registration of single-cross and trilinear hybrids with higher productivity and heterosis effects closer to 1; there is a massive increase of newly registered hybrids following Romania's entry in E.U. in 2007; there is an increase of the number of new hybrids registered in the intermediate and late FAO groups and a fast decrease in the last 10 years of the ones in extremely early and early groups; there is an increase in the registration of late hybrids which is correlated with the increase of annual average temperature in Romania, this leading to an increase in yield without any early freeze risk.

Key words: maize, hybrid type, hybrid maturity group.

INTRODUCTION

According to FAO data, present world maize production is about 1.16 billion tonnes grain from about 202 million ha (FAOSTAT, 2020). Maize's ecological flexibility make it "the plant of choice" for grain and feed in climates raging from temperate to tropical as long as there is no frost and mean temperatures are mostly above 10 degrees Celsius. Practically, maize is grown successfully from 58° N to 40° S including tropical, subtropical, and intermediate climates (Troyer, 1996). Until our times, maize has developed into one of the most important plants for the human race, being used in a wide array of fields from animal feed, starch additives, syrups, flour and many other applications.

Increase in demand of maize grain, as human population inhabiting the earth has been growing exponentially exceeding already 8 billion people, has led to a higher focus on genetics and the breeding of more and more productive cultivars of maize. The increase in world maize production in the last two decades is associated with the intensification in the use of maize hybrid seed (Chassaigne-Ricciulli et al., 2020).

The increase in the number of newly developed maize varieties, and then hybrids, at the beginning and mid 20th century made it necessary to have an independent, state controlled, process for testing and registering these hybrids in a national register of hybrids and varieties to ensure farmers that the seed available for them is superior in terms of yield and growing characteristics and to promote a healthy competition in terms of breeding in order to invest resources only in the most productive, and thus the future easiest to sell hybrids.

In the present, maize is the most grown crop in Romania (2.68 million ha in 2020 according to FAO database), this being used widely in human food and in animal feed. In fact, Romania has a long history of maize growing, the first documented report being in the 17th century, when it became essential for the everyday food of the local population.

The history of hybrid maize in Romania is impressive starting in 1957 when the first

foreign double cross hybrids were cultivated. The first double cross hybrids produced nationally were HD 208 and HD 405 registered in 1962 and 1963 respectively, which lead to their widespread use in only 7 years.

In Romania, the framework for registering new varieties and hybrids was established in 1953 by the creation of the State Committee for Testing and Homologating Varieties (HCM 3726/1953) and it has evolved nowadays into the State Institute for Testing and Registering of Varieties (ISTIS). Only varieties and hybrids registered in the Official Catalogue published annually by ISTIS can be planted in Romania (Popescu et al., 2018). Registration of new hybrids of maize needs to follow specific steps set up by ISTIS in its national network of testing centres in order to establish if they pass the D.U.S. test, which means they must be distinct from existing hybrids, they have uniform characteristic and they are stable with consistent phenotypic characteristics (ISTIS, 2020). The admission of Romania in the European Union in 2007 meant the opening of the national register to newer hybrids and varieties. European Union regulations state that a hybrid registered in the register of a member country can be automatically considered as registered in the register of any other member country i.e. Romania. This has brought the advantage of earlier access to highly developed hybrids but at the same time lost the filter of location testing in order to identify the most suitable hybrids for the growing conditions available in Romania (GEVES, 2022).

George Harrison Shull (1908) was the first maize breeder to publish a paper on the subject of crossing inbred lines of maize and the effect of heterosis the hybrid seed exhibits. Heterosis or hybrid vigour refers to the superior performance of a hybrid relative to its parents, maize showing highly significant and positive heterosis for yield and yield components (Zaid et al., 2014).

E.M. East and D.M. Jones openly promoted the use of two-way crosses between hybrids in order to obtain four-way hybrids which meant more seed to sell by breeders, essential for survivability of early maize breeding programs, and more variability than randomly cross-pollinated varieties (Crow, 1998).

In time, disadvantages of double cross hybrids such as the need of a big number of fields in order to produce the inbred lines, each two-way cross parent and the four-way cross hybrid. This together with evolution in the field of hybrid maize breeding lead to the development of more sustainable programs of single cross hybrids, as these exhibit a higher index of heterosis and thus higher yield performance together with almost perfect uniformity in the field (Beck, 2002).

Since the beginning of the 21st century the scientific world's focus has been increasingly on the potential long term negative effects of global warming. For farmers and plant breeders, the increase of the average annual temperature means the start of a race for developing and planting more late varieties of maize to take advantage of this resource. Of course, the downside of increased temperatures is the need of more and more drought tolerant hybrids in order to survive the water stress and heat and yield more than early variety maize.

The aim of this study was to evaluate how the registration of the new maize hybrids has evolved over time in Romania in term of number and type of hybrid and to see if there is any correlation between the increase of the average annual temperature and the maturity group of these hybrids.

MATERIALS AND METHODS

The primary data base for our research have been the Romanian Official Catalogues of the Varieties of Plant Species issued annually by ISTIS, from these being extracted the information regarding maize varieties and hybrids registered in Romania and the variation of these from year to year.

It was defined maturity groups according to FAO, respectively: 100-200, 200-300, 300-400, 400-500, 500-600, and 600>, later named extremely early, early, intermediate and late, each hybrid being assigned to its corresponding group. At the same time, the hybrids were centralized based by their type: single-cross, double-cross or trilinear.

Climate data was collected from variate sources in order to show the evolution of the annual mean temperature.

The number of hybrids registered by year was plotted into a chart in order to illustrate their evolution in time. There was also plotted the registrations of hybrids based on their type: single-cross, double-cross and trilinear in time to show the trend in evolution. The same method was used to show the evolution of hybrid registrations in time based on maturity groups. Statistical analysis was conducted through ANOVA analysis together with linear regression in order to determine the relationship between average mean temperature evolution and hybrid maturity.

RESULTS AND DISCUSSIONS

The result of our data analysis highlighted significant interesting facts about the evolution of maize hybrid registered for cultivation in Romania. The number of hybrids registered in Romania varied a lot in the 37 years studied, starting from 1984 with a relatively low number of 37 hybrids registered to nowadays, in 2020 with 313 hybrids registered (Table 1). This can be, of course, attributed firstly to the fact that previous to 1989, there was not a free-market economy as entry of new hybrids was strictly regulated and mostly domestically focused.

It can be observed that there are two maximum peaks regarding the number of registered hybrids: 2006 and 2016 (Figure 1). The first peak is an artificial one as it included all the hybrids including ones not used at all anymore, while after Romania's entry into the European Union in 2007, the catalogue was updated to include only active hybrids which reduced a lot the number of total registered maize hybrids. The evolution post EU membership shows us that a lot of new hybrids were registered many of them from the registers of EU member countries.

Table 1. Maize hybrids registered in Romania by maturity group

FAO Group	1984	1985	1986	1987	1989	1990	1992	1993	1995	1996	1997	1998
100-200	2	7	5	6	5	7	12	14	22	29	29	32
200-300	8	11	11	9	8	8	8	16	25	26	26	26
300-400	9	9	8	7	7	6	6	12	15	16	13	14
400-500	6	5	5	3	3	4	7	7	17	21	26	32
500-600	12	8	9	8	7	8	9	10	18	21	23	28
>600	0	4	4	5	5	4	6	8	9	12	13	17
Total	37	44	42	38	35	37	48	67	106	125	130	149
FAO Group	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
100-200	35	40	43	43	44	47	53	51	13	13	13	13
200-300	28	39	46	49	54	62	64	60	29	31	43	43
300-400	20	32	35	42	49	57	61	68	26	29	47	47
400-500	39	59	62	70	76	80	85	90	36	39	56	56
500-600	31	42	49	56	55	58	63	64	29	29	38	38
>600	18	24	24	27	30	35	42	42	9	9	11	11
Total	171	236	259	287	308	339	368	375	142	150	208	208
FAO Group	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
100-200	15	15	16	16	13	12	11	11	11	7		
200-300	58	58	78	82	89	85	77	84	70	68		
300-400	63	61	72	82	94	104	104	112	116	118		
400-500	75	80	95	102	116	106	86	91	76	71		
500-600	49	52	65	69	65	58	48	53	45	40		
>600	14	13	14	14	13	10	9	11	10	9		
Total	274	279	340	365	390	375	335	362	328	313		

From the analysis of maize hybrid registrations in Romania by their type (single-cross, double-cross or trilinear) it can be perfectly observed the evolution of breeding and the change in focus of breeding programs towards single-cross and trilinear maize hybrids in order to maximize the yield and to have the strongest heterosis effect possible (Table 2). The plot perfectly illustrates the increased focus of trilinear hybrids, in the years after joining the European Union (Figure 2).

By analysing the registration of new maize hybrids in Romania by maturity group as defined by FAO, it can be observed the tendency in registrations driven by demand of farmers, to shift from extra early and early maize hybrids toward intermediate and late hybrids registration. If there is taken into account each maturity group as a percentage out of the total number of registered hybrids, it can be seen for example that for intermediate hybrids there is a growth from 20% in average in 1980s-early 1990s up to 37% in 2020 (Figure 3). In terms of numbers, this is also evident as in 1984 there were 9 registered 300-400 FAO maize hybrids and in 2020 there were 118, a tremendous increase which shows the shift in focus of farmers and breeders alike for this maturity group, as it seems to be the most suitable for Romania's maize growing conditions (Figure 4).
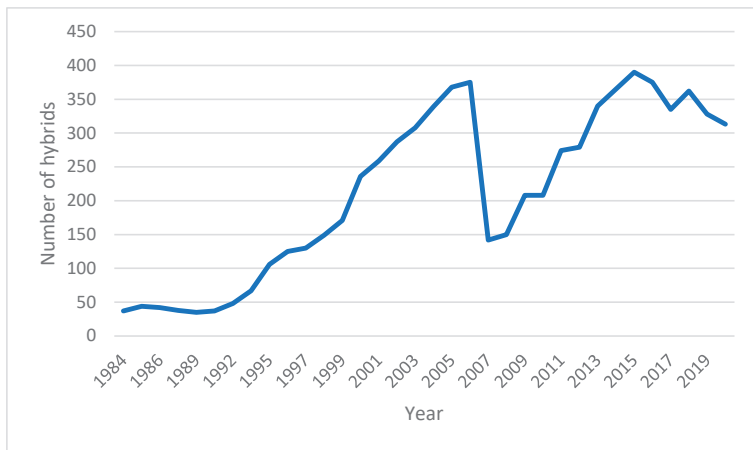

Figure 1. Evolution of the number of registered maize hybrids in Romania (1984-2020)

Table 2. Maize hybrids registered in Romania by breeding type

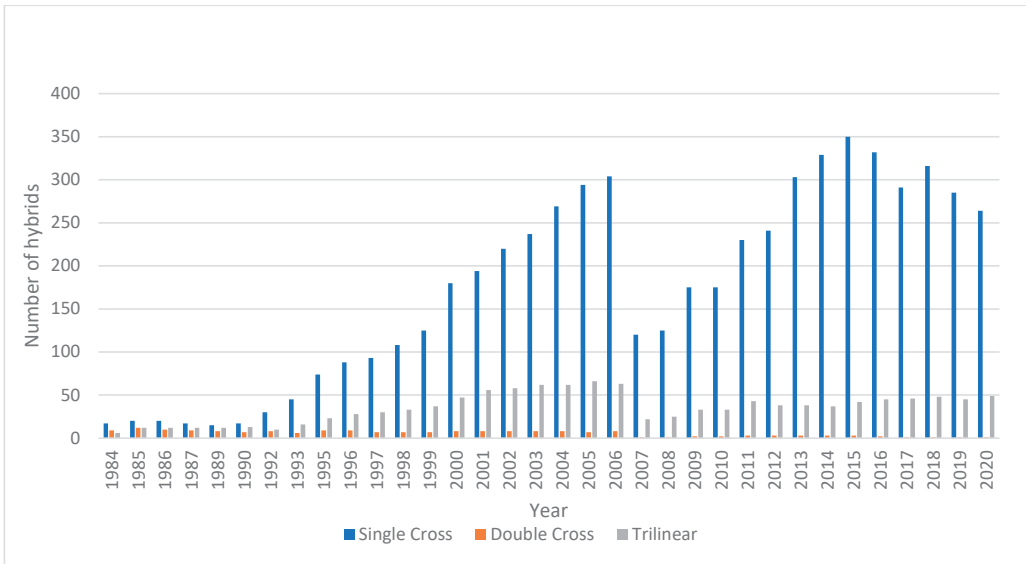| Hybrid Type	1984	1985	1986	1987	1989	1990	1992	1993	1995	1996	1997	1998
Single-Cross	20	20	20	17	15	17	30	45	74	88	93	109
Double-Cross	10	12	10	9	8	7	8	6	9	9	7	7
Trilinear	7	12	12	12	12	13	10	16	23	28	30	33
Total	37	44	42	38	35	37	48	67	106	125	130	149
Hybrid Type	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Single-Cross	126	181	195	221	238	269	295	304	119	124	173	173
Double-Cross	8	8	8	8	8	8	7	8	1	1	2	2
Trilinear	37	47	56	58	62	62	66	63	22	25	33	33
Total	171	236	259	287	308	339	368	375	142	150	208	208
Hybrid Type	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
Single-Cross	228	238	299	325	345	328	288	313	282	263		
Double-Cross	3	3	3	3	3	2	1	1	1	1		
Trilinear	43	38	38	37	42	45	46	48	45	49		
Total	274	279	340	365	390	375	335	362	328	313		

Figure 2. Evolution of registered maize hybrids in Romania by type (1984-2020)
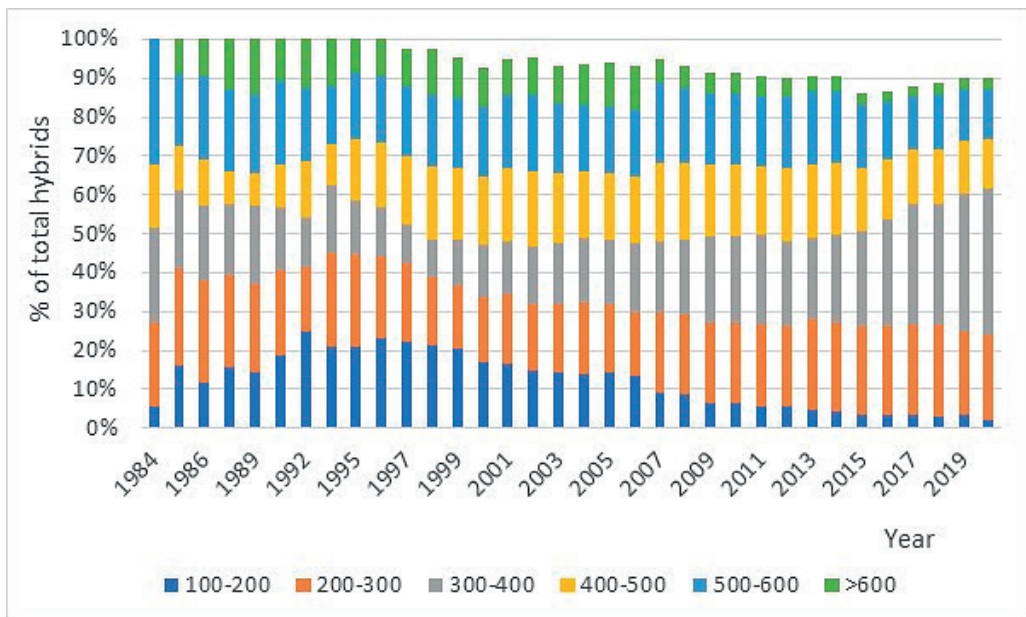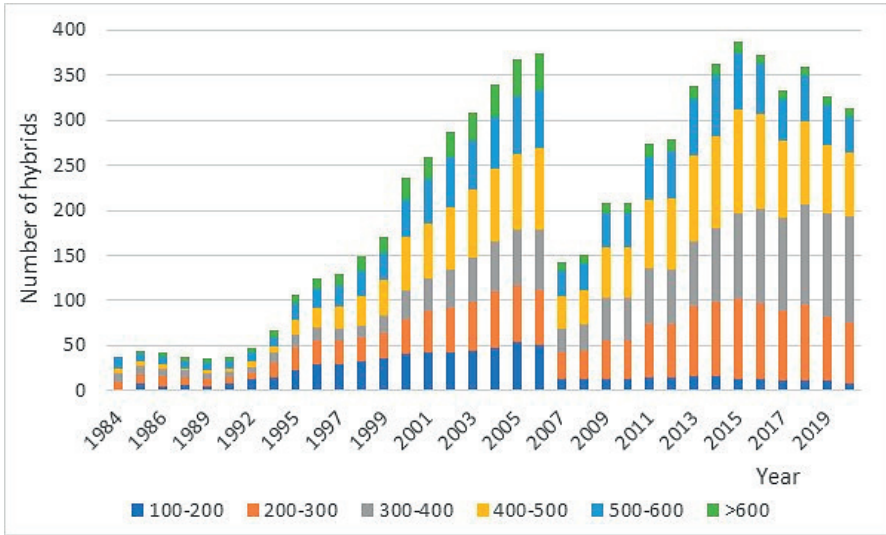

Figure 3. Maturity group evolution (%) of registered maize hybrids in Romania (1984-2020)

The average annual temperature in Romania has seen a constant growth since 1991 until nowadays, in tune with global warming as it has been observed at end of the 20th century (Figure 5). In total, there is a growth of 1.5 degrees Celsius and a constant trend of growth in terms of heat resources to support growth of intermediate and late maturity maize hybrids in Romania. There is a growth from the 1980s when average annual temperature was 8.5 degrees on average up to over 10 degrees in the 2020 (Figure 6).

Figure 4. Maturity group evolution (number) of registered maize hybrids in Romania (1984-2020)
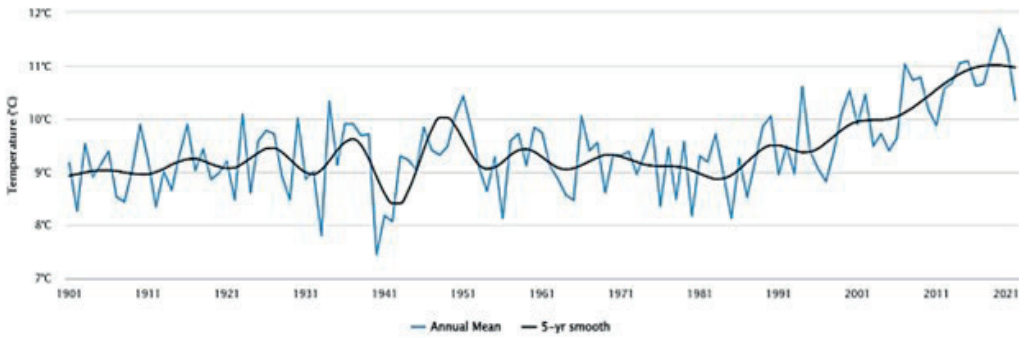

Figure 5. Historical annual mean temperature in Romania with a 5 years trailing average line
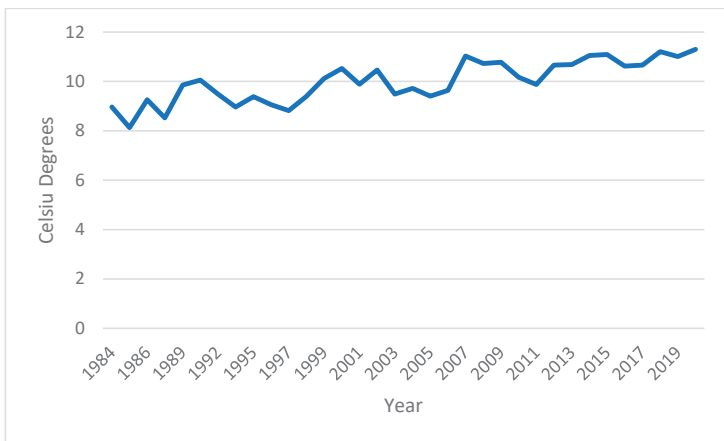(climateknowledgeportal.worldbank.org, 2021)

Figure 6. Average annual temperature in Romania, 1984-2020 (climateknowledgeportal.worldbank.org, 2021)

Statistical analysis performed using ANOVA and linear regression methods allowed us to research if there is any correlation and direct effect of the increase of average annual temperature, thus a higher level of the resource solar energy, and the registration of new hybrids by maturity group.

The value of R squared > 0.65 shows us that the number of hybrids registered per maturity group varies positively with the value of annual mean temperature (Table 3). The results of the statistical analysis performed confirms our supposition that there is a strong positive correlation between the growth of annual temperatures in Romania and the maturity of registered maize hybrids. Fisher test results show us that there is random variability and our results are statistically significant. These results allow us to present the link between the growth in average annual temperature and maturity group of the hybrids, as the 1.5 degrees growth in temperature from 1984 to 2020 is correlated with the growth in intermediate 300-400 FAO maturity maize hybrids from 9 to 118, respectively from 20% of the total number of hybrids registered in 1984 to 37% in 2020.

Table 3. Regression and ANOVA statistics

Regression Statistics					
Multiple R	0.815974156				
R Square	0.665813823				
Adjusted R Square	0.591550228				
Standard Error	0.53860766				
Observations	34				
ANOVA					
	df	SS	MS	F	Significance F
Regression	6	15.60533654	2.600889423	8.965547962	2.00079E-05
Residual	27	7.832651694	0.290098211		
Total	33	23.43798824			

CONCLUSIONS

From the analysis of the data presented in this paper one can infer that the number of hybrids registered in Romania has increased tremendously since 1990 up to 2007, when Romania joined the European Union. In 2007, the Romanian Official Catalogue was updated, which reduced significantly the number of total registered maize hybrids. The evolution post EU membership showed that a lot of new hybrids were registered many of them from the registers of EU member countries.

Also one can infer that over time, the number of double-cross hybrids registered have reduced almost completely from the Romanian Official Catalogue in favour of single-cross hybrids and trilinear ones, which are more productive, having a higher heterosis index.

In terms of maturity groups, it can be observed a certain shift, especially in the last 10 years, from extremely early and early maturity maize towards more hybrids from intermediate and late maturity groups as the increase in average temperature and warmer autumns meant that increases in yield can be achieved and early freezes have been pushed later, from late September towards early-mid October.

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