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PHENOLOGY, YIELD AND PROTEIN CONTENT OF MAIZE (*Zea mays* L.) HYBRIDS AS AFFECTED BY DIFFERENT SOWING DATES

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Abstract

The optimum sowing time and the suitable hybrid are agronomic management practices that play a major role in determining the quantity and quality of maize yield. In this study, a randomized field experiment was established at ARDS Simnic, Craiova to assess the influence of sowing dates and hybrids on phenology, grain yield and protein content of maize. The research included three sowing dates: 9th April, 16th April and 23th April. The results showed that the delayed sowing dates had higher impacts on the phenology of maize, shortened the all plant growing stages and reduced the accumulated heat units (GDD), especially after the silking stage. In early sowing date (9th April), the grain yield (GY) and heat use efficiency (HUE) were significantly higher compared to two other sowing dates, for all hybrids. Protein content of maize grain increased with delay in sowing date due to the modifications of thermal conditions during grain-filling period. Maize hybrids PR39D81 and LG3350 that produced the maximum grain yield (11.47 t/ha and 11.42 t/ha, respectively) when sown in 9th April, were the most suitable hybrids for this region.

Key words**:** *growing degree days (GDD), heat use efficiency (HUE), protein content*

INTRODUCTION

Maize (*Zea mays*. L) is an important cereal crop cultivated in almost all countries, occupying an area of approximately 194 million hectares [9] .

For Romania, maize is one of the strategic cereal crops for internal and foreign market. Therefore for Romanian farmers, the increasing maize yield must be the main objective [12, 13].

Maize grain yield and quality of maize grains are two important factors concerned in maize production because its plays a significant role in ensuring food security and in people's dietary health [14].

Maize grains are considered to be a valuable source of energy. Its protein content is of 8-12% and this value is influenced by weather factors and by genotypes [7, 10].

The sowing time is a key factor that influencing farming activities and that is highly associated with grain yield and quality of grains [1, 20].

Many previous studies have demonstrated that delayed sowing dates can result in substantial yield loss in most cases, due to shorter duration of vegetative and reproductive period [3, 18]. On the contrary, [19] demonstrated that winter maize sown at later sowing date (25 October) enhanced grain yield, quality parameters and the growth compared to early sowing (15 October). [8], also reported that delayed sowing date did not affect grain yield and protein content of maize.

Thus, the previous results were not always in consistent due to the some factors *viz.*, agronomic practices, environmental conditions and genotypes.

The Oltenia region is often affected by drought and heat, only two years out of ten are favourable to agricultural crops [5].

The phenology and grain yield under rain-fed condition are higher influenced by temperature.

Temperature based indices such as accumulated heat units or growing degree days (GDD) and heat use efficiency (HUE) can by useful for predicting crop production and growth in different environmental conditions [3].

Therefore, the main objective of this research was to assess the influence of different sowing dates and hybrids on phenology, grain yield and protein content of maize using several thermal indices.

MATERIALS AND METHODS

In 2016, the field experiment was performed at Agricultural Research and Development Station (ARDS) Simnic – Craiova, situated in the central part of the Oltenia region.

It was a two-factorial experiment, conducted in three replications. The first studied factor: (A) was the date of sowing: 9^{th} April, 16^{th} April and 23^{th} April) and second factor: (B) was the hybrid: PR38A24 (FAO 300), PR39D81 (FAO 200) and LG3350 (FAO 370).

The soil of the experiment is a reddish preluvosoil with pH = 5.08 (moderately acidic) and humus content of 2.68 % (low).

The climatic conditions during the growing period were favourable for maize crop. The precipitation of the growing season was around the multiannual average value, while temperature deviated from the multiannual average by +0.3°C.

Crop maize was fertilized with 250 kg/ha NPK 20:20:0 and 250 kg/ha ammonium nitrate. Weeds were controlled by applying DUAL GOLD 960 - 1.5 l/ha, just after sowing and EQUIP 1.5 l/ha + BUCTRIL 1.0 l/ha post emergent

Protein content of maize grains was analyzed by using Perten AM 5200-A (NIR).

Maize crop growth period was studied at three phenophases: silking stage; physiological maturity: grain-filling period (from silking to physiological maturity period).

Days to silking were recorded while 75% were visible in each plot.

Days to maturity were recorded by the appearance of black layer at the base of the grains.

The daily weather data (maximum and minimum temperature) was obtained from the Craiova Meteorological Station

The thermal indices were calculated according to the following formulas [3]:

Heat units or growing degree days (GDD):

$GDD = \Sigma [(Tmax + Tmin)/2 - Tb]$

where,

Tb = Base temperature (10°C).

Heat use efficiency (HUE):

HUE = Grain yield (kg/ha)/GDD

The data were subjected to Fisher's analysis of variance technique (ANOVA) for two factors.

The means were compared using Duncan's multiple range tests at 5% probability. Pearson's correlation coefficients were calculated on the basis of tolerant indices [15].

RESULTS AND DISCUSSIONS

Days to different phenological stages and growing degree days

Data collected on days to all phenological stages indicated significant differences ($p \leq 0.05$) for all sowing dates and for all hybrids except with physiological maturity stage when differences between hybrids were non-significant (Table 1).

The sowing date of 9 April showed higher days to silking stage (83.0), to physiological maturity stage (137.7) and to grain-filling period (54.0) for all hybrids as compared to other later sowing dates. The result indicated that delay in sowing decreased the time to attain different phenological stages of maize crop. Similar results have been reported by others studies [2, 3, 11].

Among maize hybrids, PR39D81 took longer days to silking stage (81.7), but for grain-filling period, the hybrids LG3350 and PR38A24 took longer days (53.7 and 53.3, respectively).

In term of GDD, the sowing date exhibited significant different ($p \leq 0.05$) on GDD accumulation only at grain-filling period. GDD at this period was higher for all hybrids which were sown in 9^{th} April (733.9) and 16^{th} April (720.7) followed by $23t^{th}$ April (709.0).

Maize hybrids had significant different ($p \leq 0.05$) in GDD at silking stage and at grain-filling period.

Among maize hybrids, similar results were observed: PR39D81 had higher GDD at silking stage (679.2), but at grain-filling period, the hybrids LG3350 and PR38A24 had higher GDD (735.9 and 729.9, respectively).

Table 1. Influence of sowing dates and hybrids on days and accumulated GDD to phenological stages of maize (after sowing)

Factors	Silking		Physiological maturity		Grain –filling period	
	Days	GDD	Days	GDD	Days	GDD
			Sowing dates (A)			
9th April	83.0[a]	648.7	137.7[a]	1,370.9	54.0[a]	733.9[a]
16th April	79.3[b]	656.7	132.0[b]	1,365.2	52.3[b]	720.7[a]
23th April	74.0[c]	644.5	125.3[c]	1,349.2	51.3[b]	709.0[ab]
F test	*	NS	*	NS	*	*
			Hybrids (B)			
PR38A24	77.0[b]	632.3[b]	131.0	1,349.9	53.3[a]	729.9[a]
PR39D81	81.7[a]	679.2[a]	132.3	1,372.2	50.7[b]	697.8[b]
LG3350	77.7[b]	638.3[b]	131.7	1,363.2	53.7[a]	735.9[a]
F test	*	*	NS	NS	*	*

*Significance at $p \leq 0.05$; NS =Non-significant; Means followed by different letters in each column are significantly different from each other at 5% level of significance
Source: Own calculation.

Grain yield and protein content of maize

From the data presented in the Table 2 showed that the grain yield and protein content were significantly (at $p \leq 0.05$) affected for all sowing dates and for all maize hybrids tested.

Table 2. Influence of sowing dates and hybrids on grain yield and protein content of maize

Factors	Grain yield (t/ha)	Protein content (%)
	Sowing dates (A)	
9th April	11.31[a]	12.94[b]
16th April	11.01[b]	12.94[b]
23th April	10.26[c]	13.29[a]
F test	*	*
	Hybrids (B)	
PR38A24	10.65[b]	13.28[a]
PR39D81	11.03[a]	12.91[b]
LG3350	10.90[a]	12.99[b]
F test	*	*

*Significance at $p \leq 0.05$;
Means followed by different letters in each column are significantly different from each other at 5% level of significance
Source: Own calculation.

Grain yield obtained in 9th April (11.31 t/ha) was recorded highest as compared to other sowing dates (11.01 t/ha and 10.26 t/ha, respectively).

Higher yield in early sowing can be due to longer growth cycle and favourable temperatures during grain-filling period. Similar observations under delayed sowing have been reported by [2, 21].

Among maize hybrids, PR39D81 and LG 3350 have had highest grain yield (11.03 t/ha and 10.90 t/ha, respectively) compared to PR38A24 (10.65 t/ha)

In term of protein content, 23th April sowing maize hybrids had highest ($p \leq 0.05$) protein content (13.29%) but remaining both sowing dates (9th April and 16th April) that had similar protein content (12.94%).

Thus, higher delay in sowing increases the content of protein in grains due to the modifications of thermal conditions during grain-filling period.

A similar result was found to the findings of [18], according to low temperature in the early stages of development reduces protein content of maize grains.

On the contrary, [11] reported that the protein content was decreased with the delaying sowing date due to decreasing the time of growth period and seed filling. [8], also reported that delayed sowing date did not affect yield and protein content of maize.

This result confirms the impact of weather conditions in the different regions.

Among maize hybrids, PR38A24 (13.28%) have higher protein content compared to other hybrids.

[4], reported that the grain yield of maize was negative and significant correlated with

protein content and with air temperature for the maize crop sown in the central part of the Oltenia region.

[6], also confirmed that the average temperature during grain-filling period is one the dominant climatic factors which explains 94.6% of inter-annual variability of maize yield.

Heat use efficiency

In terms of HUE was observed that all the maize hybrids were more efficient in using heat units at early sowing date (9th April) than the late sowing dates (16th April and 23th April) as presented in Table 3. Similar results have been reported for maize by [3, 16].

Table 3. Heat use efficiency (HUE) for grain yield of different maize hybrids as affected by sowing dates

Hybrids	HUE			Reduction or increase (%) due to late sowing		
	9th April	16th April	23th April	9th April *vs* 16th April	9th April *vs* 23th April	16th April *vs* 23th April
PR38A24	8.11	7.76	7.78	4.32	4.06	+0.25
PR39D81	8.34	8.13	7.63	2.52	8.51	6.15
LG3350	8.30	8.29	7.39	0.12	10.96	10.85

Source: Own calculation.

A higher value HUE represents that plants utilized the heat units more efficiently by increasing biological activity and productivity [17].

Under late sowing dates (16th April and 23th April), all maize hybrids had reduced HUE at different magnitude compared to early sowing date, following the same trend, except the hybrid PR38A24.

The reductions in HUE for hybrids PR39D81 and LG3350 were higher for 9th April *versus* 23th April (8.51% and 10.96%, respectively) and for 16th April *versus* 23th April (6.15 and 10.85%, respectively) and were less for 9th April *versus* 16th April (2.52% and 0.12%, respectively). Therefore, it can be concluded that these hybrids are the more suitable hybrids for early spring sowing.

For hybrid PR38A24, the HUE reduction was higher for 9th April *versus* 16th April (4.32%) and for 9th April *versus* 23th April (4.06%), but for 16th April *versus* 23th April HUE was little increased (+0.25%), which confirmed that this hybrid can be sown at any time.

Correlation analysis

From the data presented in Table 4 showed that the grain yield of maize was highly significant positive correlated with days at physiological maturity stage (r = 0.751**; p = 0.01), with days at silking stage (r = 0.789**; p = 0.01) and with HUE (r = 0.950**; p = 0.01), and also was significant negative correlated with protein content (r = -0.414^{0}; p = 0.05).

This result indicated that maize hybrids with had a longer growing cycle (sowing to maturity period) achieved a higher grain yield because they used more efficient heat units.

In this study, the hybrid PR39D81 took longer time to attain these stages and showed the highest grain yield followed by LG3350.

Similar results have been reported by [1] for maize sowing in spring season at Multan, Punjab, Pakistan.

Protein content had negative and significant correlattions with days at silking stage (r = -0.556^{00}; p = 0.01), with days at physiological maturity stage (r = -0.505^{00}; p = 0.01), with GDD at silking stage (r = -0.482^{0}; p = 0.05) and with GDD at physiological maturity stage (r = -0.614^{00}; p = 0.01) –Table 4.

Days at silking stage had positive and significant correlations with days to maturity stage (r = 0.865**; p = 0.01), with GDD at silking stage (r = 0.568**; p = 0.01), with GDD at physiological maturity stage (r = 0.580**; p = 0.01) and with HUE (r = 0.640**; p = 0.01).

Days at maturity stage had positive and significant correlations with GDD at physiological maturity stage (r = 0.629**; p = 0.01) with days during grain-filling period (r = 0.479*; p = 0.05) and with HUE (r = 0.585**; p = 0.01).

Days during grain-filling period had a significant negative correlation with GDD at silking stage (r = -0.423^{0}; p = 0.05), but had a significant positive correlation with GDD during grain-filling period (r = 0.962**; p = 0.01).

GDD at silking stage was significant negative correlated with GDD during grain-filling period (r = -0.471^{0}; p = 0.05).

Table 4. Pearson correlation coefficients of grain yield and protein content with thermal indices at different phenological stages under different sowing dates (n = 27)

Item	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
GY(1)	-	-0.414^{0}	0.789**	0.751**	0.168	0.270	0.321	0.060	0.950**
PC (2)		-	-0.556^{00}	-0.505^{00}	-0.026	-0.482^{0}	-0.614^{00}	0.037	-0.236
Days at S (3)			-	0.865**	0.153	0.568**	0.580**	0.050	0.640**
Days at PM (4)				-	0.479*	0.157	0.629**	0.365	0.585**
Days at GF (5)					-	-0.423^{0}	0.158	0.962**	0.127
GDD at S (6)						-	0.357	-0.471^{0}	0.166
GDD at PM (7)							-	0.137	0.010
GDD at GF (8)								-	0.021
HUE at PM (9)									-

*, ^{0}, **, ^{00} = significant positive or negative at 0.05 and 0.01 levels, respectively; GY = grain yield; PC = protein content; S = silking stage; PM = physiological maturity stage; GF = grain-filling period

Source: Own calculation.

CONCLUSIONS

This study showed that the delayed sowing dates had higher impacts on the phenology of maize, shortened the all plant growing stages and reduced the GDD especially in grain-filling period. Thus, early sowing of maize hybrids can be recommended to the farmers for this area.

Maize sowing on 9th April had higher grain yield, GDD and HUE for all hybrids as compared to other later sowing dates.

Among the maize hybrids, PR39D81 and LG3350 obtained the better grain yields but with a lower protein content.

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