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GRAIN YIELD OF MAIZE HYBRIDS FROM DIFFERENT MATURITY GROUPS INFLUENCED BY NITROGEN AND PHOSPHORUS FERTILISATION

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Abstract

Understanding the relationship between yield and macronutrients fertilization is essential in maize cultivation technology, especially in non-irrigated conditions that require the rational use of water and fertilizers to ensure efficient crops. From this point of view, the purpose of the research was to determine the influence of mineral fertilization with nitrogen (N) and phosphorus (P) on the yield of different maturity groups maize hybrids and the identification of those hybrids with the best adaptation to the specific soil and climatic conditions of the area (Sarichioi, Tulcea County, Dobrogea). The research involved sowing eight maize hybrids from different maturity groups: early hybrids (DKC 3623 - FAO 260 and P8567 - FAO 275), mid-early hybrids (DKC 4590 - FAO 350 and P9903 - FAO 360), mid-late hybrids (DKC 4717 - FAO 410, P0023 - FAO 400 and P0412 - FAO 480) and late hybrids (DKC 5632 - FAO 510) under different mineral fertilization conditions with doses of nitrogen (N) and phosphorus (P) (N_0P_0; $N_{60}P_0$; $N_{60}P_{60}$; $N_{120}P_{60}$). Nitrogen fertilization led to a yield increase with values between 7.50 kg/kg N a.s. (for the hybrid P99038) and 10.75 kg/kg N a.s. (at P99038 hybrid), and application of phosphorus resulted in yield increases from 4.17 kg/kg P a.s. (P8567 and P0412) to 5.67 kg/kg P a.s. (DKC 4590). The eight hybrids responded to fertilization with nitrogen and phosphorus, their yield ranging from 6.46 t/ha for the hybrid DKC 3623 hybrid unfertilized to 9.09 t/ha to for the hybrid P0412 fertilized $N_{120}P_{60}$. On average, mid-late hybrids (FAO 400-480) recorded the highest yields with values between 7.35 t/ha and 8.77 t/ha.

Key words*: Zea may hibrids, FAO maturity groups, grain yield, fertilization, Dobrogea area.*

INTRODUCTION

Fertilization is essential for the corn crop technology, directly related to its yield and other productivity elements.

Nitrogen (N) plays a fundamental role in the nutrition of corn plants (Sangoi L., 2001; Miao Y. et al., 2006; Al-Naggar A.M.M., 2015; Gidea M. et al., 2015; Prisecaru G. et al., 2017), in their vegetative development and in yield implicitly. Following water, nitrogen is the second most important factor that influences corn yield (Ran H. et al., 2017). Phosphorus (P) is of particular importance in root formation and increase in drought resistance, photosynthesis and in the transport and activation of enzymes, while the lack of phosphorus can directly influence yield (Pettigrew W.T., 2008). Numerous researches demonstrated the direct proportional relationship between fertilization with these macronutrients and corn yield. Nitrogen fertilization produces the highest yield increases of 2 to 6 t/ha depending on soil fertility (Berca M. & Buzatu C.S., 2011).

Long-term research on a clay-sandy soil in NV China has shown that in the absence of fertilization grain yield has diminished at the end of the experimentation period, representing 28.2% of the yield obtained in the first year of research, but the yield obtained in response to fertilization with nitrogen and phosphorus have improved over time (Yang S. et al., 2004).

In the field conditions of southern Romania (INCDA Fundulea, on a chernozem soil type), to ensure a yield of more than 9 t/ha, the required amount of nitrogen was between 140 and 166 kg N/ha and phosphorus must be provided at doses of 41-73 kg P/ha (Habdan V.G., 2009). In irrigated conditions, the average yield was between 12.1 and 26.8 kg grains/kg N, and for non-irrigated crop yield increases were from 10.8 to 24.6 kg grains/kg N (Habdan V.G., 2009).

Research in Kansas, United States, demonstrated a maximization of corn yield under the application of a 185 kg N/ha (Gehl R.J. et al., 2005).
Research carried out in eastern Romania (SCDA Secuieni, on a cambic chernozem) shows that with nitrogen fertilization, for every kg of applied fertilizer the average grain yield increase was between 12.21 and 19.54 kg/kg N, while the increases brought by phosphorus fertilization were between 6.42-8.83 kg/kg P (Lupu C., 2012). Lazin V.L. (2014) obtains, within the research carried out in Călăraşi County, southern Romania yields ranging from 600 to 1400 kg/ha due to nitrogen and phosphorus fertilization.
Phosphorus fertilization using doses of 60-80 kg P/ha during a 5 years research in China highlighted the assurance of a yield between 5-6 t/ha, the efficiency of phosphorus capitalization being 29%. (Xu T. et al., 2008).
Although the positive influence of fertilization on corn yield was evidenced by extensive research, this is equally influenced by environmental factors (soil type, rainfall, soil water reserve) as well as other technological factors (crop rotation, soil tillage systems, integrated pest management technologies (Marin D.I et al., 2011) generating differentiated results, which impose optimal, locally adapted fertilization strategies.
Use of fertilizers without regard to soil and climatic conditions specific to the growing area, and the use hybrids inappropriate to these conditions are the main yield limits of the corn crop (Kogbe J.O.S., Adediran J.A., 2003, Tahir M. et al., 2008). The objective of the research was to determine the influence of mineral fertilization with N and P on the yield of corn hybrids from different maturity groups and to identify those hybrids with the best adaptation to the climatic and pedologic conditions in Dobrogea (Sarichioi, Tulcea).

MATERIALS AND METHODS

The field research was located in Sarichioi, Tulcea County, within the SC Transmeteorit SRL farm. The soil specific to this area is part of the Chernozems class.
During the growing season of corn crop, the climatic data presented in Figure 1 highlight temperature values higher than the multiannual values.
Thus, we can observe that in both agricultural years there was an increase of the average temperature in May-September compared to the multiannual value specific for the area, with differences of 1.3°C in 2016 and 1.5°C in 2017.

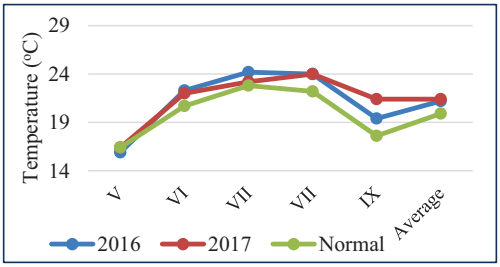

Figure 1. Temperature (°C) during maize vegetative development, Sarichioi, Tulcea County

In 2016, during the corn crop vegetative period, rainfalls of 164.9 mm were recorded, with a negative difference of 10.8 mm from the multiannual average (Figure 2). The highest rainfall values were recorded in May and June, with differences from the multiannual value of 39.3 mm and 8.3 mm, respectively. In 2017, the amount of rainfalls between May and September was 47.8 mm higher than the multi-year value (175.7 mm), with positive differences in June (38.5 mm) and July (59.8 mm).

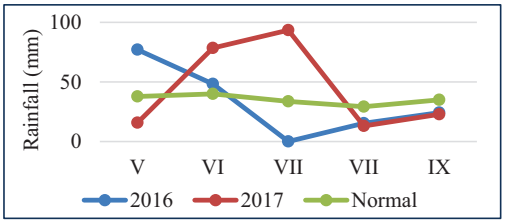

Figure 2. Rainfall (mm) during maize vegetative development, Sarichioi, Tulcea County

To achieve the research objective, a bifactorial 4 x 8 type field experience was established. The field was organized by the split plot method, with 4 replications. Within the research, the following factors were tested:
Factor A, representing the fertilization level with the following graduations:
$a_1 = N_0P_0$
$a_2 = N_{60}P_0$
$a_3 = N_{60}P_{60}$
$a_4 = N_{120}P_{60}$

Factor B, different FAO groups hybrids, with the following graduations:
b_1 = DKC 3623 (FAO 260) - early hybrid;
b_2 = P8567 (FAO 275) - early hybrid;
b_3 = DKC 4590 (FAO 350) - mid-early hybrid;
b_4 = P9903 (FAO 360) - mid-early hybrid;
b_5 = DKC 4717 (FAO 410) - mid-late hybrid;
b_6 = P0023 (FAO 400) - mid-late hybrid;
b_7 = P0412 (FAO 480) - mid-late hybrid;
b_8 = DKC 5632 (FAO 510) - late hybrid.

Corn was sown after winter wheat; soil tillage was done by plowing in autumn at a depth of 25 cm and seedbed preparation was carried out in spring at a depth of 5-6 cm.
Sowing was carried out on 13.04.2016 and 25.04.2017 at a density of 60,000 germinal seeds/ha. The crop was harvested in the second decade of September.
Fertilization was performed at the preparation of the seedbed and during vegetative development.
Weed control was carried out with Adengo 465 SC, at a dose of 0.35 l/ha applied pre-emergence and with Equip g/l at a dose of 1.7 l/ha applied post-emergence. Control of *Tanymecus dilaticollis* pests was performed using Calypso 480 SC at a dose of 90 ml/ha.

RESULTS AND DISCUSSIONS

Fertilization influence on maize yield, Sarichioi, Tulcea

Mineral fertilization with nitrogen and phosphorus resulted in yield increases statistically assured compared to the unfertilized control variant. $N_{60}P_0$ fertilization produced a minimal yield increase compared to control for all researched hybrids (Table 1), the statistically assured yield growths ranging from 0.66 t/ha for DKC 4590 (FAO 350) to 1.09 t/ha for P0412 (FAO 480). The highest yield increases, very significant in statistical terms, were generated by complex fertilization $N_{120}P_{60}$ (Table 1). Yield increases determined by 120 kg N/ha and 60 kg P/ha active substance fertilization had values between 1.19 t/ha for the hybrid P9903 (FAO 360) and 1.54 t/ha for the hybrid P0412 (FAO 480).
Due to $N_{60}P_{60}$ complex mineral fertilization, yield increased significantly, with values between 0.98 t/ha for P9903 (FAO 360) hybrid and 1.34 t/ha for P0412 hybrid (FAO 480).

Table 1. Fertilization influence on grain yield (GY, t/ha), Sarichioi, Tulcea County

Maize hybrid	NP level	Grain yield			
		GY t/ha	Diff. %	Diff. t/ha	Signf.
DKC 3623 (FAO 260)	**N_0P_0**	**6.46**	**100.00**	**Ct**	**-**
	$N_{60}P_0$	7.20	111.55	0.75	**
	$N_{60}P_{60}$	7.46	115.57	1.01	***
	$N_{120}P_{60}$	7.71	107.05	1.25	***
P8567 (FAO 275)	**N_0P_0**	**6.80**	**100.00**	**Ct**	**-**
	$N_{60}P_0$	7.61	111.92	0.81	**
	$N_{60}P_{60}$	7.86	115.60	1.06	***
	$N_{120}P_{60}$	8.09	106.38	1.30	***
DKC 4590 (FAO 350)	**N_0P_0**	**6.90**	**100.00**	**Ct**	**-**
	$N_{60}P_0$	7.57	109.63	0.66	**
	$N_{60}P_{60}$	7.91	114.58	1.01	***
	$N_{120}P_{60}$	8.29	109.53	1.39	***
P9903 (FAO 360)	**N_0P_0**	**7.26**	**100.00**	**Ct**	**-**
	$N_{60}P_0$	7.95	109.46	0.69	**
	$N_{60}P_{60}$	8.25	113.56	0.98	***
	$N_{120}P_{60}$	8.46	106.37	1.19	***
DKC 4717 (FAO 410)	**N_0P_0**	**7.05**	**100.00**	**Ct**	**-**
	$N_{60}P_0$	7.89	111.88	0.84	**
	$N_{60}P_{60}$	8.17	115.77	1.11	***
	$N_{120}P_{60}$	8.35	105.83	1.30	***
P0023 (FAO 400)	N_0P_0	**7.45**	**100.00**	**Ct**	**-**
	$N_{60}P_0$	8.24	110.61	0.79	**
	$N_{60}P_{60}$	8.55	114.84	1.11	***
	$N_{120}P_{60}$	8.87	107.71	1.43	***
P0412 (FAO 480)	N_0P_0	**7.55**	**100.00**	**Ct**	**-**
	$N_{60}P_0$	8.64	114.44	1.09	**
	$N_{60}P_{60}$	8.89	117.75	1.34	***
	$N_{120}P_{60}$	9.09	105.21	1.54	***
DKC 5632 (FAO 510)	N_0P_0	**7.20**	**100.00**	**Ct**	**-**
	$N_{60}P_0$	7.96	110.68	0.77	**
	$N_{60}P_{60}$	8.26	114.82	1.07	***
	$N_{120}P_{60}$	8.47	106.38	1.28	***
Hybrids average	N_0P_0	**7.08**	**100.00**	**Ct**	**-**
	$N_{60}P_0$	7.88	111.28	0.80	**
	$N_{60}P_{60}$	8.17	115.32	1.09	***
	$N_{120}P_{60}$	8.42	118.83	1.33	***

LSD 5% = 0.44 t/ha; LSD 1% = 0.61 t/ha; LSD 0.1% = 0.84 t/ha
*ns - not significant; * significant; ** distinctly significant; *** very significant*

Analyzing the influence of mineral fertilization on the average yield of the eight hybrids, increases recorded compared to unfertilized control were between 11.28% ($N_{60}P_0$) and 11.83% ($N_{120}P_{60}$), statistically assured for all fertilization levels (Table 1).
Yield increase achieved by applying one kg of nitrogen (N) active substance was on average 8.75 kg, ranging between 7.50 kg for P9903 and 10.75 kg for P0412 (Figure 3).

The average grain yield growth (Figure 3) per kg of phosphorus (P) active substance was 4.83 kg, the highest capitalization of a kg of phosphorus active substance was recorded by DKC 4590 (5.67 kg) hybrid, and the lowest by the hybrids P8567 and P0412 (4.17 kg).

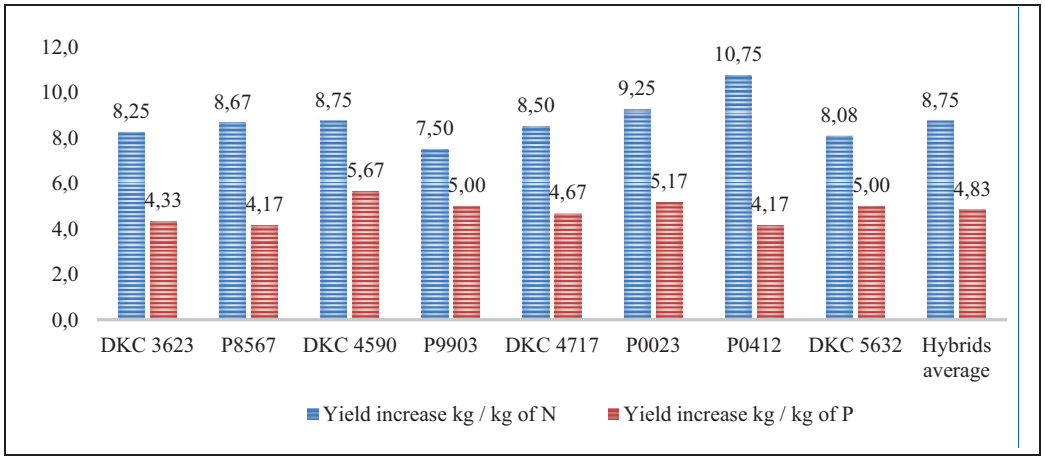

Figure 3. Yield increase kg grains per kg of mineral fertilizer active substance: nitrogen and phosphorus

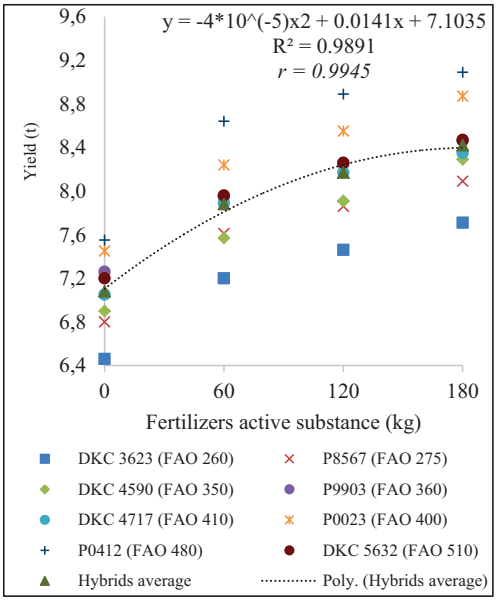

Figure 4. Graphical distribution of grain yields as influenced by doses of active substance fertilizers

For all eight hybrids data presented in Figure 4 highlights a relationship of interdependence between the grain yield and the amount of fertilizer active substance applied.

On average, under non-irrigated conditions, the correlation coefficient of 0.9945 reveals a strong dependence between yield and the amount of fertilizer the active substance applied. The value of the regression coefficient indicates that about 98.91% of the corn crop yield is provided by the applied fertilizer dose of the active substance (Figure 4).

Hybrid influence on maize yield, Sarichioi, Tulcea

The eight corn hybrids recorded an average yield of 7.08 t/ha for the non-fertilized variant (N_0P_0) and 8.42 t/ha when mineral fertilization $N_{120}P_{60}$ was (Table 2).

The lowest yield values were obtained by the hybrid DKC 3623 (between 6.46 t/ha in the unfertilized variant and 7.71 t/ha for the fertilization level $N_{120}P_{60}$) and the P0412 hybrid recorded the highest yields (between 7.55 t/ha, unfertilized and 9.09 t/ha, fertilized $N_{120}P_{60}$).

Under the influence of the hybrid, compared to the average yield the eight hybrids grain yield recorded differences were between -0.71 t/ha and 0.76 t/ha. The hybrids DKC 3623, P8567 and DKC 4590 obtained for all fertilizer levels researched lower yield values, with differences between -0.71 t/ha (at DKC 3623 fertilized with $N_{60}P_{60}$ and $N_{120}P_{60}$) and -0.13 t/ha (at hybrid DKC 4590 fertilized with $N_{120}P_{60}$).

For DKC 3623 hybrid, yield difference compared to control (average yield of the hybrids) was significantly negative, while for the other hybrids the differences recorded were not statistically assured.

Table 2. Hybrid influence on grain yield (GY, t/ha), Sarichioi, Tulcea County

NP fertilization level	Maize hybrid	Grain yield			
		GY (t/ha)	Diff. %	Diff. t/ha	Signif.
N_0P_0	DKC 3623 (FAO 260)	6.46	91.16	-0.63	oo
	P8567 (FAO 275)	6.80	95.94	-0.29	ns
	DKC 4590 (FAO 350)	6.90	97.47	-0.18	ns
	P9903 (FAO 360)	7.26	102.54	0.18	ns
	DKC 4717 (FAO 410)	7.05	99.57	-0.03	ns
	P0023 (FAO 400)	7.45	105.12	0.36	ns
	DKC 5632 (FAO 510)	7.20	101.60	0.11	ns
	P0412 (FAO 480)	7.55	106.60	0.47	*
	Average hybrids	**7.08**	**100.00**	**Ct**	**-**
$N_{60}P_0$	DKC 3623 (FAO 260)	7.20	91.38	-0.68	oo
	P8567 (FAO 275)	7.61	96.49	-0.28	ns
	DKC 4590 (FAO 350)	7.57	96.02	-0.31	ns
	P9903 (FAO 360)	7.95	100.86	0.07	ns
	DKC 4717 (FAO 410)	7.89	100.11	0.01	ns
	P0023 (FAO 400)	8.24	104.48	0.35	ns
	DKC 5632 (FAO 510)	7.96	101.05	0.08	ns
	P0412 (FAO 480)	8.64	109.62	0.76	**
	Average hybrids	**7.88**	**100.00**	**Ct**	**-**
$N_{60}P_{60}$	DKC 3623 (FAO 260)	7.46	91.35	-0.71	oo
	P8567 (FAO 275)	7.86	96.17	-0.31	ns
	DKC 4590 (FAO 350)	7.91	96.85	-0.26	ns
	P9903 (FAO 360)	8.25	100.98	0.08	ns
	DKC 4717 (FAO 410)	8.17	99.97	0.00	ns
	P0023 (FAO 400)	8.55	104.68	0.38	ns
	DKC 5632 (FAO 510)	8.26	101.16	0.09	ns
	P0412 (FAO 480)	8.89	108.84	0.72	**
	Average hybrids	**8.17**	**100.00**	**Ct**	**-**
$N_{120}P_{60}$	DKC 3623 (FAO 260)	7.71	91.61	-0.71	oo
	P8567 (FAO 275)	8.09	96.13	-0.33	ns
	DKC 4590 (FAO 350)	8.29	98.50	-0.13	ns
	P9903 (FAO 360)	8.46	100.48	0.04	ns
	DKC 4717 (FAO 410)	8.35	99.21	-0.07	ns
	P0023 (FAO 400)	8.87	105.39	0.45	*
	DKC 5632 (FAO 510)	8.47	100.67	0.06	ns
	P0412 (FAO 480)	9.09	108.01	0.67	**
	Average hybrids	**8.42**	**103.04**	**Ct**	**-**
LSD 5% = 0.46 t/ha; LSD 1% = 0.60 t/ha; LSD 0.1% = 0.78 t/ha					

*ns – not significant, * significant, ** distinctly significant, *** very significant*

On the opposite side hybrids P9903, P0023, DKC 5632 and P0412 (Table 2) recorded higher yields for all fertilization levels compared to the average hybrids yield, and differences were positives with values between 0.04 t/ha (P9903 hybrid fertilized with $N_{120}P_{60}$) and 0.76 t/ha (in P0412 hybrid fertilized with $N_{60}P_0$), being significantly positive for hybrid P0412, unfertilized (0.47 t/ha) and for the hybrid fertilized P0023 $N_{120}P_{60}$ (0.45 t/ha) distinctly positive for P0412 fertilized with $N_{60}P_0$, $N_{60}P_{60}$ and $N_{120}P_{60}$ and not statistically assured for the other hybrids.

The hybrid DKC 4717 recorded yield differences between -0.07 t/ha ($N_{120}P_{60}$) and 0.18 t/ha (N_0P_0) compared to the control (Table 2), but not assured statistically.

Analyzing the influence of the maturity group on hybrids yield, the data presented in Table 3 shows that the semi-late hybrids recorded the highest yield values for all fertilization levels ranging between 7.35 t/ha for the unfertilized variant and 8.77 t/ha for $N_{120}P_{60}$ fertilization. The lowest yield values were obtained by early hybrids, with values between 6.63 t/ha (unfertilized) and 7.90 t/ha ($N_{120}P_{60}$).

Table 3. Grain yield (t/ha) differences among maturity groups, Sarichioi, Tulcea County

NP fertilization level	Grain yield (t/ha)				Differences among maturity groups (t/ha)****					
	Early hybrids (b_{1-2})	*Mid-early hybrids* (b_{3-4})	*Mid-late hybrids* (b_{5-7})	*Late hybrids* (b_8)	b_{3-4} - b_{1-2}	b_{5-7}-b_{1-2}	b_8-b_{1-2}	b_{5-7}-b_{3-4}	b_8-b_{3-4}	b_8-b_{5-7}
N_0P_0 (a_1)	6.63	7.08	7.35	7.20	0.46*	0.72**	0.57**	0.27^{ns}	0.11^{ns}	-0.15^{ns}
$N_{60}P_0$ (a_2)	7.40	7.76	8.26	7.96	0.36^{ns}	0.85***	0.56**	0.50*	0.21^{ns}	-0.29^{ns}
$N_{60}P_{60}$ (a_3)	7.66	8.08	8.54	8.26	0.68**	1.13***	0.86***	0.46*	0.18^{ns}	-0.27^{ns}
$N_{120}P_{60}$ (a_4)	7.90	8.37	8.77	8.47	0.97***	1.37***	1.07***	0.40*	0.10^{ns}	-0.30^{ns}
LSD 5% = 0.39 t/ha; LSD 1% = 0.54 t/ha; LSD 0.1% = 0.74 t/ha										

*ns - not significant, * significant, ** distinctly significant, *** very significant; ****differences were calculated among the average yield of the hybrids belonging to a FAO maturity group*

Compared to early hybrids (Table 3), mid-early hybrids recorded yield increases of 0.36 t/ha (fertilization level $N_{60}P_0$) and 0.97 t/ha (fertilization level $N_{120}P_{60}$), statistically assured for the unfertilized variant and for the use of $N_{60}P_{60}$ and $N_{120}P_{60}$.

Compared to early hybrids both late and mid-late hybrids recorded higher yields with distinctly significant differences of 0.72 t/ha and 0.57 t/ha respectively for the unfertilized variant and very significant differences between 0.85 t/ha and 1.37 t/ha for the variants where mineral fertilization with nitrogen and phosphorus was applied (Table 3).

Compared with mid-early hybrids, semi-late hybrids recorded higher yields with statistically significant differences between 0.40 t/ha and 0.50 t/ha obtained where mineral fertilization was applied (Table 3).

The yield of late hybrids was higher than that recorded by mid-early hybrids, and increased with values between 0.10 t/ha and 0.21 t/ha were not statistically assured. Compared to mid-late hybrids, the late ones recorded lower yields, with statistically significant differences, ranging from 0.15 t/ha to 0.30 t/ha (Table 3).

CONCLUSIONS

The results obtained during the period 2016-2017 under the conditions of Dobrogea area (Sarichioi locality, Tulcea County) reveal the positive influence of mineral fertilization with nitrogen and phosphorus on the grain yield of the eight corn hybrids.

Under the influence of fertilization, the yield of the eight corn hybrids recorded statistical assured growths compared to the unfertilized control variant, ranging from 0.66 t/ha for DKC 4590 fertilized with $N_{60}P_0$ to 1.43 t/ha for P0023 fertilized with $N_{120}P_{60}$.

Nitrogen fertilization resulted in an average yield increase of 8.75 kg grains per kg N, and phosphorus fertilization provided an average increase of 4.83 kg grains per kg of P.

The highest yields were recorded by the mid-. late hybrid P0412, with values between 7.55 t/ha (unfertilized) and 9.09 t/ha ($N_{120}P_{60}$).

Under the pedologic and climatic conditions of Sarichioi, Tulcea county, the highest yields are recorded by the mid-late hybrids, with values between 7.35 t/ha (unfertilized) and 8.7 t/ha ($N_{120}P_{60}$).

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