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MAIZE YIELD RECORDED IN RAINFED CONDITIONS OF SOUTHEASTERN ROMANIA AS INFLUENCED BY FERTILIZATION RATES AND HYBRID

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Abstract

Maize is a staple food worldwide, and the issues of growing it in current drought-oriented scenario of climate change rise challenges in agricultural practices, especially for the rainfed agriculture that is widely extended in Romania. The current paper presents the results of a field research conducted during 2017 and 2018 at Moara Domnească Didactic Farm, located in Southeastern Romania, aiming to highlight the influence of technological factors, as fertilization and hybrid, on maize yield recorded in rainfed conditions. Rainfalls capitalization by the maize crop shows yield increases between 25.2 kg and 37.8 kg grains per mm rainfalls, depending on hybrid and fertilization rates. The highest yield is recorded by the hybrid DKC 5086 (8512,7 kg/ha) at the fertilization level $N_{80}P_{40}$. Yield growth generated by mineral fertilization recorded an average value for the researched hybrids of 14.1 kg per kg of nitrogen applied and of 9.1 kg per kg of phosphorus.

Key words*: maize, rainfalls, nitrogen, phosphorus, yield.*

INTRODUCTION

Favorable growing conditions in Romania allowed maize crops (*Zea mays* L.) to have a positive dynamic, from ensuring 2.2% of the global maize yield in 1998 (Lăzăroiu et al., 2008) to being placed secondly in terms of yield and first in terms of surface in the European Union and in Romania (Ion et al., 2013). In 2018 Romania was first country in EU in terms of maize yield (USDA, Circular-Series, 2019).

Maize nutritional value but also its biological characteristics turn it into a valuable species of the *Poaceae* family, grown worldwide in 166 countries, thus being the second grown crop at global level after *Triticum aestivum* (Roman et al., 2011; Rouf-Shah et al., 2016; CONABIO, 2017; Ghete et al., 2018).

In countries from Latin America and Africa, maize is a vital source of food, a staple food for millions of people, thus it's growing being an issue of food security (Jones & Thornton, 2003; Ramirez-Cabral et al., 2017).

Romanian farmers currently benefit of a large assortment of maize hybrids from different precocity groups for a proper capitalization of soil and climatic conditions specific to cropping area and depending on the applied technology (Dumbravă et al., 2016; 2017).

In terms of cropping technology, fertilization is an important factor because it influences yield and yield indicators (Ion et al., 2015; Băşa et al., 2016). Nitrogen (N) is in general the most important macronutrient in crop's development, with a 50% rate of influence on the increase of global grains yield (Erisman et al., 2008) but also influencing yield inferior limits (Blumenthal et al., 2008) especially associated with water availability (Bacon 2004; Huang et al., 2006).

Maize has a superior capitalization of N fertilization, especially in a three years crop rotation compared to monoculture (Ciontu et al., 2012). For extra-early hybrids, nitrogen (along with foliar fertilization) in a maize crop irrigated with a volume of 900 m^3 water generated the best biomass yield increase for maize grown in successive crop at Moara Domnească (Mureşeanu et al., 2014). Other research conducted at Moara Domnească (Ciontu et al., 2011; Gidea et al., 2015)

highlight a significant yield increase and a positive economic return proportional to the increase of the N fertilization rate obtained for the maize crop in a three years rotation system, while similar research conducted by Bășa et al. (2016) highlight the importance of phosphorus (P) along with N fertilization.

MATERIALS AND METHODS

The experimental field was located at Moara Domnească Didactic Farm (belonging to University of Agronomic Sciences and Veterinary Medicine of Bucharest), on a chromic luvisol. The experimental design was based on two factors. Experimental variants had a surface of 56 square meters (8 rows with a length of 10 m at a distance of 70 cm between rows) and where arranged as split blocks with four replications.

Studied factors consisted of five maize hybrids (*Zea mays* L.) of different FAO (350-510) and three fertilization levels:

Factor A - fertilization levels:

- A_1 - N_0P_0 (**Ct**)
- A_2 - $N_{80}P_0$
- A_3 - $N_{80}P_{40}$.

Factor B - maize hybrids:

- B_1 - DKC 4590
- B_2 - DKC 5068
- B_3 - P9911
- B_4 - P0216
- B_5 - OLT

Sowing was conducted with a SPC-6 sowing machine on April 13, 2017 and on April 18, 2018 at a density of 62,000 of plants/ha, at a distance of 70 cm between rows. Fertilizers were applied gradually during seed bed preparation with a dose of 50 kg/ha active substance N:P (20: 20: 0), and with a dose of 30 kg/ha nitrogen active substance as ammonium nitrate during vegetative development.

Weed control was conducted chemically in preemergence with Dual Gold 960 EC (*s-metholachlor* 960 g/l) at a dose of 1.3 l/ha, and in postemergence with DicopurTop 464 SL (*2.4 D 344* g/l + *dicamba* 120 g/l) with a dose of 1.1 l/ha. Mechanical weed control consisted of two harrows applied during vegetative development. Climatic conditions were analyzed during plants vegetative development and compared to the multiannual values specific for the area. Thus, during crops vegetative development (April-August) average monthly temperature of the two years (2017-2018) was 21.4°C by 1.4°C over the multiannual value, while rainfalls amount recorded in the same period recorded for the two years an average monthly value of 243.8 mm, cu 71.9 mm lower that the multiannual value. July was highlighted because the difference recorded compared to the multiannual value was 43.3 mm (Table 1).

Table 1. Climatic data during maize vegetative development, average 2017-2018, Moara Domnească

Month	Temperature (°C)		Rainfall (mm)		
	Avg. monthly 2017-2018	Normal	Avg. monthly 2017-2018	Normal	Diff. compared to Normal
April	16.5	16.4	45.0	48.1	**- 3.1**
May	19.2	19.7	23.7	67.7	**- 44.0**
June	22.5	22.5	50.0	86.3	**- 36.3**
July	24.7	23.0	106.4	63.1	**+ 43.3**
August	24.2	20.4	18.7	50.5	**- 31.8**
Avg. or Sum	**21.4**	**20.4**	**243.8**	**315.7**	**- 71.9**

RESULTS AND DISCUSSIONS

Yield growth as influenced by rainfall

Average maize yield growth determined by 1 mm rainfall was 28.9 kg/mm for the fertilization N_0P_0, 34.1 kg/mm when $N_{80}P_0$ was applied and 35.8 kg/mm for $N_{80}P_{40}$ fertilization (Table 2). The lowest yield increase recorded under the influence of rainfall was obtained by Olt hybrid for the unfertilized variant (28.7 kg/mm). The highest yield increase generated by rainfall was recorded at the fertilization level $N_{80}P_{40}$ (37.8 kg/mm) by DKC 5068 hybrid, a mid-late hybrid that capitalized through its vegetative development higher rainfalls recorded especially in June and July.

An interdependence was observed when analyzing maize yield related to rainfall amount during the vegetative development of the crop, highlighted by a correlation coefficient r = 0.7669 (Figure 1). Considering regression analysis results around 59% (R^2 = 0.5881) of the maize yield increase can be associated to the amount of rainfall fallen during maize crop vegetative development.

Table 2. Maize yield increase (kg) per mm of rainfall, (Moara Domnească, 2017-2018)

Hybrid	Fertilization level	Yield increase (kg/mm rainfall)
DKC 4590	$N_0 P_0$	28.9
	$N_{80} P_0$	34.1
	$N_{80}P_{40}$	35.8
DKC 5068	$N_0 P_0$	30.1
	$N_{80} P_0$	36.1
	$N_{80}P_{40}$	37.8
P9911	$N_0 P_0$	27.3
	$N_{80} P_0$	32.0
	$N_{80}P_{40}$	33.7
P0216	$N_0 P_0$	28.7
	$N_{80} P_0$	33.6
	$N_{80}P_{40}$	35.2
OLT	$N_0 P_0$	25.2
	$N_{80} P_0$	29.4
	$N_{80}P_{40}$	30.8
Average hybrids	$N_0 P_0$	28.9
	$N_{80} P_0$	34.1
	$N_{80}P_{40}$	35.8

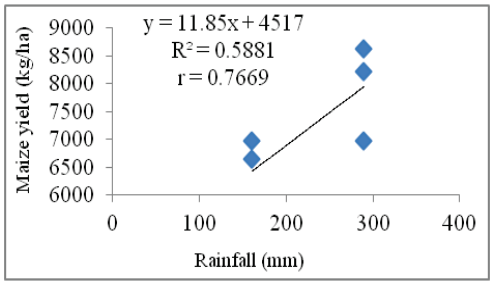
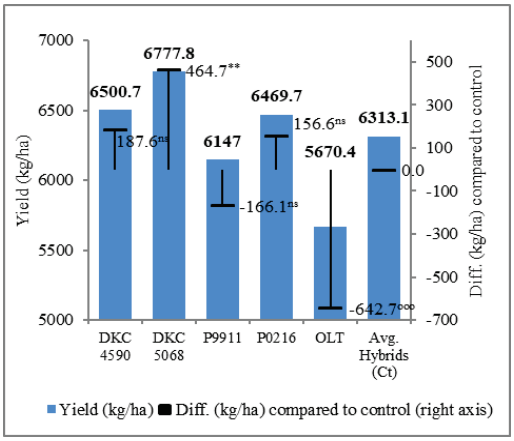


Figure 1. Rainfall influence (mm) on grain yield

Yield recorded in rainfed conditions as influenced by hybrid.

For the unfertilized variant (Figure 2) the five maize hybrids recorded an average yield (control) of 6313.1 kg/ha. Compared to control the highest yield increase, distinctly significant in statistical terms, was recorded by DKC 5068 (464.7 kg/ha), while the highest decrease was obtained by Olt hybrid, with a very significant negative difference of -642.7 kg/ha.



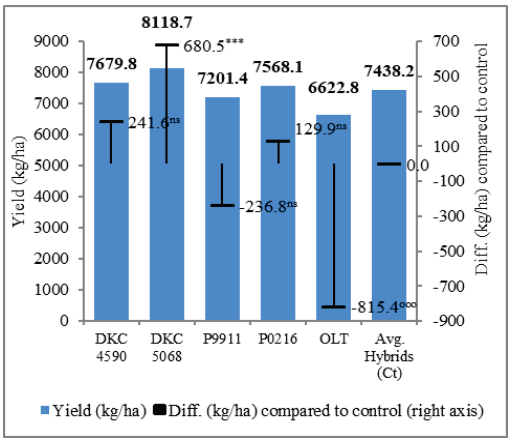
LSD 5% = 325.0 kg/ha; LSD 1% = 455.6 kg/ha; LSD 0.1% =644.0 kg/ha

Figure 2. Hybrid influence on grain yield for the fertilization level $\mathbf{N_0P_0}$

Other researched hybrids obtained yield differences compared to control with values between -166.1 kg/ha and 187.6 kg/ha, but non-significant in statistical terms (Figure 2).

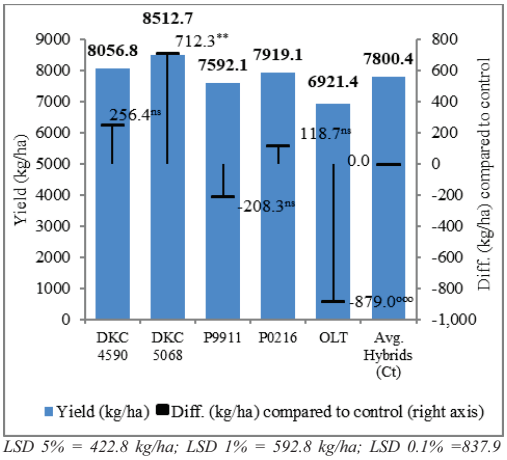
DCK 5068 hybrid obtained the highest yield (8118.7 kg/ha) for the fertilization level $\mathbf{N_{80}P_0}$, with a very significant increase of 680.5 kg/ha compared to the average yield of the hybrids (control) (Figure 3). The smallest yield was recorded by Olt (6622.8 kg/ha), with a very significant difference of -815.4 kg/ha from control (Figure 3). Hybrids DKC 4590 and P0216 recorded yield increases from control, but non-significant in statistical terms, while hybrid P9911 had a negative difference from control but not statistically assured.

For the variant fertilized $\mathbf{N_{80}P_{40}}$ (Figure 4) a distinctly significant yield growth of 712.3 kg/ha compared to control was recorded by the hybrid DCK 5068, thus obtaining also the highest grain yield with a value of 8512.7 kg/ha. Hybrids DCK 4590 and P0216 also had higher yield than the average value but the differences were not statistically assured. Smaller yields than the average were recorded by P9911 and Olt, only the latest having a very significant negative difference of -879.0 kg/ha.



LSD 5% = 403.2 kg/ha; LSD 1% = 565.2 kg/ha; LSD 0.1% =798.9 kg/ha

Figure 3. Hybrid influence on grain yield for the fertilization level $\mathbf{N_{80}P_0}$



LSD 5% = 422.8 kg/ha; LSD 1% = 592.8 kg/ha; LSD 0.1% =837.9 kg/ha

Figure 4. Hybrid influence on grain yield for the fertilization level $\mathbf{N_{80}P_{40}}$

Compared to DCK 4590 hybrid (b_1), DKC 5068 (b_2) was the only one that recorded higher yields with statistically assured differences for the fertilized variants (Tabel 3). Hybrids P9911 (b_3), P0216 (b_4) and Olt (b_5) had lower yields, with differences statistically assured only for P9911 and Olt. These hybrids also had lower yields than DKC 5068 (with distinctly significant (b_4-b_2, except the unfertilized variant) and very significant differences (b_3-b_2, b_5-b_2) for all fertilization levels. Compared to the hybrid P9911, P0216 recorded higher yields with a significant difference only for the fertilized variant N_{80} P_0, while Olt had lower yields with statistically significant differences. Olt also recorded lower yields compared to P0126, the negative differences being very significant in statistical terms.

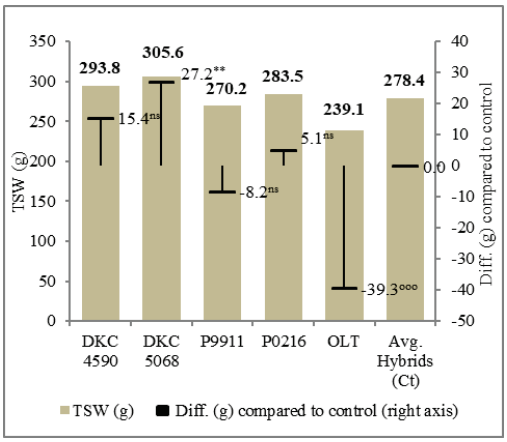
Thousand seeds weight (TSW) recorded in rainfed conditions as influenced by hybrid

Hybrid influence on maize thousand seeds weight obtained for the unfertilized variant (Figure 5) reflects on TSW increase for the hybrid DKC 5068 with a distinctly significant difference (27.2 g) compared to the average value of the hybrids (control). Positive influence of the hybrid on TSW was also recorded for DKC 4590 and P0216 hybrids, but increases compared to control were not statistically assured. P9911 had a lower yield than control with a insignificantly, with an non-significant negative difference (-8.2 g), while Olt recorded the smallest TSW with a very significant difference compared to control (-39.3 g).

Table 3. Yield differences among maize hybrids (Moara Domnească, 2017-2018)

Fertilization level	b_2-b_1	b_3-b_1	b_4-b_1	b_5-b_1	b_3-b_2	b_4-b_2	b_5-b_2	b_4-b_3	b_5-b_3	b_5-b_4
N_0P_0	277.1^{ns}	-353.7^{o}	-31.0^{ns}	-830.3^{ooo}	-630.8^{ooo}	-308.1^{ns}	-1107.4^{ooo}	322.7^{ns}	-476.6^{oo}	-799.3^{ooo}
$N_{80}P_0$	438.9*	-478.4^{oo}	-111.7^{ns}	-1057.0^{ooo}	-917.3^{ooo}	-550.6^{oo}	-1495.9^{ooo}	366.7*	-578.6^{oo}	-945.3^{ooo}
$N_{80}P_{40}$	455.9**	-464.7^{oo}	-137.7^{ns}	-1135.4^{ooo}	-920.6^{ooo}	-593.6^{oo}	-1591.3^{ooo}	327.0^{ns}	-670.7^{ooo}	-997.7^{ooo}

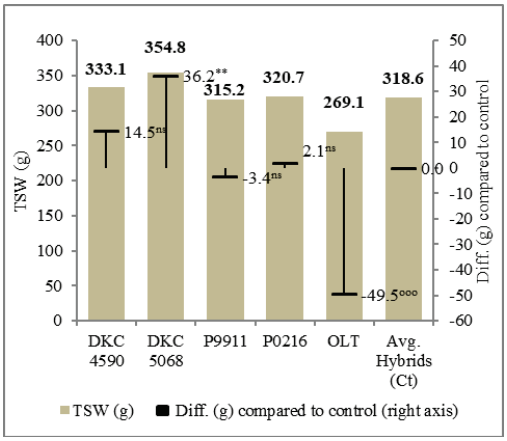
LSD 5% = 332.4 kg/ha; LSD 1% = 453.4 kg/ha; LSD 0.1% =613.9 kg/ha



LSD 5% = 15.6 g; LSD 1% = 21.8 g; LSD 0.1% = 30.9 g

Figure 5. Hybrid influence on TSW for the fertilization level **N_0P_0**

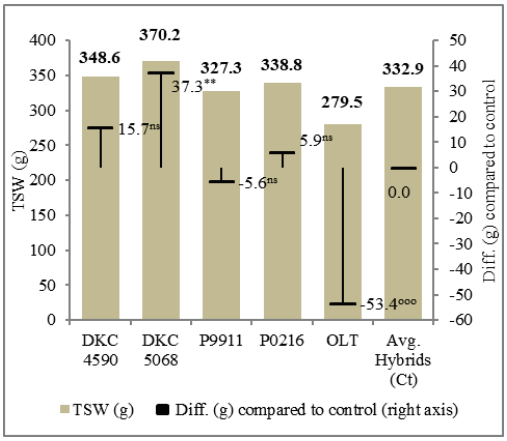
For the fertilization level $N_{80}P_0$ hybrid DKC 5068 recorded the highest and also distinctly significant TSW increase compared to control (average TSW of the hybrids). The smallest TSW with the greatest negative difference (-49.5), very significant in statistical terms was recorded by Olt hybrid (Figure 6). Hybrids DKC 4590, P9911 and P0216 varied compared to control in statistical terms but the recorded differences either negative or positive where not statistically assured.



LSD 5% = 18.6 g; LSD 1% = 26.1 g; LSD 0.1% = 36.9 g

Figure 6. Hybrid influence on TSW for the fertilization level **$N_{80}P_0$**

On the fertilization level **$N_{80}P_{40}$** (Figure 7) a distinctly significant compared to control growth of 37.3 g was recorded by the hybrid DCK 5068, this recording the highest TSW. Hybrids DCK 4590 and P0216 also recorded higher differences but not statistically assured. Smaller TSW compared to the average were recorded by P9911 and Olt, only the latest having a very significant negative difference.



LSD 5% = 19.4 g; LSD 1% = 27.2 g; LSD 0.1% = 38.5 g

Figure 7. Hybrid influence on TSW for the fertilization level **$N_{80}P_{40}$**

Grain yield and TSW variation under different fertilization rates

Fertilization positively influenced both maize yield and a thousand seeds weight compared to control, unfertilized variant (Table 4). For the average yield of the five hybrids nitrogen fertilization at a rate of 80 kg N a.s./ha generated a very significant yield increase of 1125.0 kg/ha, while complex mineral fertilization with N_{80} P_{40} determined also a very significant yield increase of 1487.3 kg/ha. The highest yield increase compared to the unfertilized variant was recorded by the DKC 5068 fertilized N_{80} P_{40} (1734.9 kg/ha) while the smallest growth was recorded by Olt fertilized with $N_{80}P_0$ (952.4 kg/ha). Both differences were very significant positive. Due to fertilization a thousand seeds weight recorded very significant differences compared to control (unfertilized variant) for all the researched hybrids. The average TSW increased by 40.1 g for the fertilization level $N_{80}P_0$ and by 54.4 g for the fertilization level $N_{80}P_{40}$ (Table 4).

Table 4. Fertilization influence on maize yield and TSW
(Moara Domnească, 2017-2018)

Hybrid	Fertilization level	Yield (kg/ha)	%	Diff. (t/ha)	Signf.	TSW (g)	%	Diff. (g)	Signf.
DKC 4590	**N_0 P_0**	6500.7	**100.0**	**Ct**	-	293.8	**100.0**	**Ct**	-
	N_{80} P_0	7679.8	118.1	1179.10	***	333.1	113.4	39.30	***
	$N_{80}P_{40}$	8056.8	123.9	1556.10	***	348.6	118.7	54.80	***
DKC 5068	**N_0 P_0**	6777.8	**100.0**	**Ct**	-	305.6	**100.0**	**Ct**	-
	N_{80} P_0	8118.7	119.8	1340.9	***	354.8	116.1	49.2	***
	$N_{80}P_{40}$	8512.7	125.6	1734.9	***	370.2	121.1	64.6	***
P9911	**N_0 P_0**	6147.0	**100.0**	**Ct**	-	270.2	**100.0**	**Ct**	-
	N_{80} P_0	7201.4	117.2	1054.4	***	315.2	116.7	45.0	***
	$N_{80}P_{40}$	7592.1	123.5	1445.1	***	327.3	121.1	57.1	***
P0216	**N_0 P_0**	6469.7	**100.0**	**Ct**	-	283.5	**100.0**	**Ct**	-
	N_{80} P_0	7568.1	117.0	1098.4	***	320.7	113.1	37.2	***
	$N_{80}P_{40}$	7919.1	122.4	1449.4	***	338.8	119.5	55.3	***
OLT	**N_0 P_0**	5670.4	**100.0**	**Ct**	-	239.1	**100.0**	**Ct**	-
	N_{80} P_0	6622.8	116.8	952.4	***	269.1	112.5	30.0	***
	$N_{80}P_{40}$	6921.4	122.1	1251.0	***	279.5	116.9	40.4	***
Average hybrids	**N_0 P_0**	6313.1	**100.0**	**Ct**	-	278.4	**100.0**	**Ct**	-
	N_{80} P_0	7438.2	117.8	1125.0	***	318.6	114.4	40.1	***
	$N_{80}P_{40}$	7800.4	123.6	1487.3	***	332.9	119.6	54.4	***

LSD 5% = 330.9 kg/ha; LSD 1% = 442.8 kg/ha; LSD 0.1% =581.5 kg/ha

LSD 5% = 14.8 g; LSD 1% = 19.8 g; LSD 0.1% = 26.0 g

Correlation coefficient analysis confirms the strong dependency relation (r = 0.9951), for the field conditions of the current research, between maize yield and the amount of fertilizers active substance applied (Figure 8).

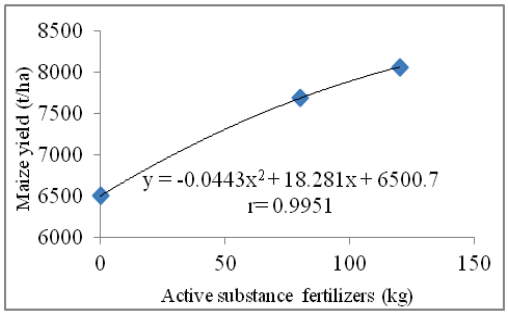


Figure 8. Fertilizer active substance influence on maize yield

Yield increase (Table 5) generated by nitrogen fertilization varied between 11.9 kg per kg of nitrogen active substance (Olt $N_{80}P_0$) and 16,8 kg per kg of nitrogen active substance (DKC 5068 $N_{80}P_0$). Yield growth generated by phosphorus fertilization recorded values from 7.5 kg/kg a.s. P and 9.9 kg/kg a.s. P. On average a kg of phosphorus generated a yield increase of 9.1 kg, while nitrogen generate an average yield growth of 14.1 kg.

Table 5. Yield increase (kg) per kg of fertilizer active substance (Moara Domnească, 2017-2018)

Hybrid	Fertilization level	Yield increase (kg/kg a.s. N)	Yield increase (kg/kg a.s. P)
DKC 4590	N_{80} P_0	14.7	-
	$N_{80}P_{40}$	-	9.4
DCK 5068	N_{80} P_0	16.8	-
	$N_{80}P_{40}$	-	9.9
P9911	N_{80} P_0	13.2	-
	$N_{80}P_{40}$	-	9.8
P0216	N_{80} P_0	13.7	-
	$N_{80}P_{40}$	-	8.8
Olt	N_{80} P_0	11.9	-
	$N_{80}P_{40}$	-	7.5
Average hybrids	N_{80} P_0	14.1	-
	$N_{80}P_{40}$	-	9.1

CONCLUSIONS

Considering this research results we can conclude that maize yield was significantly influenced both by fertilization and hybrid, while its increase was also conditioned by the amount of rainfall during the vegetative period. The use of nitrogen based mineral fertilizers generated an average yield increase of 117.8% compared to the unfertilized variant, and a TSW increase of 114.4%, while complex fertilization $N_{80}P_{40}$ generated an average yield growth of 123.6% and a average TSW increase of 119.6%.

Hybrid influence was highlighted by distinctly significant yield growths recorded by DCK 5068 compared to the average yield of the hybrids for all fertilization levels and very significant negative differences recorded by Olt hybrid.

Yield analysis under the combined influence of fertilization and rainfall highlights the following:

- a kg per ha of nitrogen generates an average yield increase of 14.1 kg;
- a kg per ha of phosphorus determines an average yield growth of 9.1 kg;
- a mm of rainfall generates yield increases between 25.2 kg and 37.8 kg.

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