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THE EFFECTS OF SIDE-DRESSING DIFFERENT RATES AND RELEASE TYPES OF NITROGEN FERTILIZER ON HYBRID SEED MAIZE PRODUCTION

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ABSTRACT

Chemical fertilizers have been for a long time similar to the original ones created in the 1960's, only recently with the increase emphasis on environmental impact, and the need to reduce quantities of fertilizers used, we have seen the introduction of slow-release and controlled release fertilizers from small surface high value crops towards large field crop production. Side-dressing N fertilizers in maize crops has been a standard in Europe for more than 50 years and thus still has a wide rate of adoption in farms, as it has been the easiest option to apply nitrogen closer to the maximum consumption point, which starts after the plant reaches 8 leaves stage (BBCH-18). Thus, our research has focused on studying the impact of using different rates of nitrogen (40, 80 and 120 kg/ha) of the new release types of fertilizers (Urea NG, Multicote 34-0-7) side-dressing and to establish if there is any benefit, in hybrid seed maize production, of substituting classical fertilizers (ammonium nitrate) with newer ones.

The study has been conducted for 3 years in irrigated field research plots in the soil and climatic conditions from north-east of Romania. Our research has revealed several key aspects in terms of the effect on vegetative and generative development of hybrid seed maize plants: longer vegetation period for plants fertilized with slow and controlled release fertilizers, better use of the nitrogen from classical fertilizers as their availability for uptake overlaps with the needs of the plant starting from the side-dress moment. Other aspects evidentiated are reduction in quantity of fertilizer needed, thus economic benefits and similar yield with classical nitrogen fertilizer dressing.

Keywords: maize, N side-dressing, slow-release fertilizers, controlled release fertilizers, hybrid seed.

INTRODUCTION

At a time when the global population has surpassed 8 billion people (Politico, 2022), and it is continuing its trend of growth which projects a population of over 10 billion, increasing yields and capacities of production are becoming paramount objectives of scientists and farmers across the world. At the same time there is increased pressure from the civil society to be more responsible and sustainable regarding the environment when producing crops (Ma et al., 2021).

The more so as it is estimated that about half of the world's population is now dependent on nitrogen fertilizers to provide them with food (Constantinescu et al., 2023). One focus where improvements can be made in terms of environmental and economic impact is crop fertilization, where nitrogen run-off as well as the quantity of nitrogen applied could be better managed (Mikkelsen, 2021). Maize has been one of the most important crops cultivate worldwide, due to its high yielding potential, better phytotechnical package and due to improvement of hybrids cultivated (Haspel, 2015). The surfaces of maize cultivated worldwide will continue increasing as Central and South Africa transitions from proso millet (*Panicum milliaceum*) towards extra early maize varieties, only this transition possibly would add another 80 million hectare of maize production world-wide (Doctor, 2020).

To sustain such an increase in surface of maize there is of course an ever increasing requirement of high quality maize seed. Maize seed production is a technology and

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human intensive process with high costs and high income potential, thus new technologies are more easily adopted due to interest by farmers to increase their income and due to the fact that cost wise they are more easily managed (MacRobert et al., 2014). Seed production imposes several complex processes and elements that must be met in order to achieve high yields with the imposed genetic purity requirements, such as ensuring the coincidence of the flowering of inbred lines so that there is a good pollination in order to have proper fecundation of all potential grains and detaselling (remove tassels from the female parents) at the right time in order to preserve genetic purity and achieve the lowest yield loss.

Maize fertilization systems have been built around the classical products of chemical synthesis of type 1:1:1 or 1:3:0, urea or ammonium nitrate, all developed in the 1950's (Hergert et al., 2015). All these types of fertilizers are used by the plants based on the old concept of solubilization and uptake by the root system. Unfortunately, these fertilizers are very sensible to excess water and thus levigation as well as, in the case of urea, to volatilization, which makes unused N to reach levels of 50% out of the applied quantity (Schwenke, 2022). Split application of nitrogen fertilizer on maize crop has been studied and showed increase performance in yield when nitrogen is split applied later in vegetation compared to the beginning or before planting (Panison et al., 2019). There has been research regarding different methods of split application of nitrogen for maize, and when comparing top-dressing to side-dressing as methods, the conclusion was that side-dressing brings multiple advantages such as reduced volatilization, mobilization of water in the soil and lack of foliage burn (Tamil Nadhu University, 2014). Thus, side-dressing nitrogen has been the solution found by scientists and engineers to apply (Wortmann, 2022) it nearer to the massive increase in consumption by the plant which starts near BBCH-18 (eight leaf stage) until BBCH-51 (tasseling) during which 75% of its total N is used by the plant (Bender et al., 2013). Depending on the type of N fertilizer used ammonium nitrate or urea, volatilization rates during the hot days of summer are high as the fertilizer is only superficially incorporated and thus still exposed if it doesn't rain in the first week since application (Schwenke, 2021). This pass in vegetation can become an expendable cost, considering that in irrigated fields with modern herbicides available, cultivation of crops only for weeding purposes is most often not necessary. This pass with a cultivator was mostly necessary for side-dress application of nitrogen fertilizer closer to the moment of consumption.

The need to prevent nitrogen levigation in water sources, especially those close to drinking water, and managing fertilizer losses due to lack of correlation with plant pattern uptake has been an object of study for researchers in light of new environmental demands. New types of fertilizers, slow-release and controlled-release, which have a longer period of solubilization, which in some cases can be 4 months long, have appeared as a new idea for field crops (Trenkel, 2020). They are not a novelty in terms of technology as they have been used in horticultural production systems since 2000s especially in Israel (Haifa group) (Shaviv, 2001).

The question arising from the apparition of these new varieties of fertilizer is if they could alter modern technology of crop production, and thus of hybrids seed maize production, and have no negative effects on production, nicking at pollination, plant development. Potential economic benefits due to lower losses of plant population due to driving over plants, reducing the number of passes over the land, reduction of quantity of N fertilizer needed as there is less loss due to levigation or volatilization, all might recommend slow and controlled release fertilizers as a future substitute to classical fertilization systems.

The aim of this study is to evaluate the effects of different rates of nitrogen fertilization, comparing classical and new slow-release and controlled release fertilizes, on the inbred lines of the maize hybrid P9889.

MATERIAL AND METHODS

Research was organized in experimental fields, organized based on the requisites of technical experimentation plots, in 2020, 2021 and 2022 on chernozem soil situated in the Moldavian Plain, near the Romanian-Moldavia border (NE Romania), in Bivolari commune, Iaşi County, geographical coordinates 47.5188° N, 27.4490° E. Test variants used in the experiments were based on different application rates of N fertilizer and different types of N fertilizers compared with the control variant, which is the classic fertilization scheme used by the farmer under the direct supervision of the field and quality control representative of the hybrid's owner company.

Organizing the field experience was done using the concepts of scientifically technic experimentation plots, subdivided with 4 replications on the type 3x4 using the following graduated factors (Table 1):

- Factor A – Nitrogen rate applied at side-dressing:
  - a0 = 0 kg/ha (control variant);
  - a1 = 40 kg/ha;
  - a2 = 80 kg/ha;
  - a3 = 120 kg/ha.
- Factor B – type of nitrogen fertilizer:
  - b1 = Ammonium nitrate;
  - b2 = Urea;
  - b3 = Urea NG;
  - b4 = Multicote (4) 34-0-7.

Table 1. The experimental factors

Experimental factors	Fertilizer products	Fertilizer application period	Fertilizer rate (kg/ha)	Nutrients rate (kg/ha)						
				N	P	K	S	Mg	Ca	Zn
a0b0 (C - control)	Ammonium nitrate	Autumn (preceding year)	100	33.5	0	0	0	0	0	0
	18:46:0	Seedbed preparation	175	31.5	80.5	0	0	0	0	0
	Total C			*65*	*80.5*	*0*	*0*	*0*	*0*	*0*
a1b1	Ammonium nitrate	BBCH-18 sidedressing	119.4	40	0	0	0	0	0	0
	Total C + Ammonium nitrate			*105*	*80.5*	*0*	*0*	*0*	*0*	*0*
a1b2	C + Urea	BBCH-18 sidedressing	86.9	40	0	0	0	0	0	0
	Total C + Urea			*105*	*80.5*	*0*	*0*	*0*	*0*	*0*
a1b3	C + Urea NG	BBCH-18 sidedressing	86.9	40	0	0	0	0	0	0
	Total C + Urea NG			*105*	*80.5*	*0*	*0*	*0*	*0*	*0*
a1b4	C + Multicote (4) 34-0-7	BBCH-18 sidedressing	117.6	40	0	8.2	0	0	0	0
	Total C + Multicote (4)			*105*	*80.5*	*8.2*	*0*	*0*	*0*	*0*
a2b1	C + Ammonium nitrate	BBCH-18 sidedressing	238.8	80	0	0	0	0	0	0
	Total C + Ammonium nitrate			*145*	*80.5*	*0*	*0*	*0*	*0*	*0*
a2b2	C + Urea	BBCH-18 sidedressing	173.9	80	0	0	0	0	0	0
	Total C + Urea			*145*	*80.5*	*0*	*0*	*0*	*0*	*0*
a2b3	C + Urea NG	BBCH-18 sidedressing	173.9	80	0	0	0	0	0	0
	Total C + Urea NG			*145*	*80.5*	*0*	*0*	*0*	*0*	*0*
a2b4	C + Multicote (4) 34-0-7	BBCH-18 sidedressing	235.3	80	0	16.5	0	0	0	0
	Total C + Multicote (4)			*145*	*80.5*	*16.5*	*0*	*0*	*0*	*0*
a3b1	C + Ammonium nitrate	BBCH-18 sidedressing	358.2	*120*	*0*	*0*	*0*	*0*	*0*	*0*
	Total C + Ammonium nitrate			*185*	*80.5*	*0*	*0*	*0*	*0*	*0*
a3b2	C + Urea	BBCH-18 sidedressing	260.8	*120*	*0*	*0*	*0*	*0*	*0*	*0*
	Total C + Urea			*185*	*80.5*	*0*	*0*	*0*	*0*	*0*
a3b3	C + Urea NG	BBCH-18 sidedressing	260.8	*120*	*0*	*0*	*0*	*0*	*0*	*0*
	Total C + Urea NG			*185*	*80.5*	*0*	*0*	*0*	*0*	*0*
a3b4	C + Multicote (4) 34-0-7	BBCH-18 sidedressing	352	*120*	*0*	*24.6*	*0*	*0*	*0*	*0*
	Total C + Multicote (4)			*185*	*80.5*	*24.6*	*0*	*0*	*0*	*0*

Slow-release fertilizers are the type of fertilizers based on the technology of nitrification and urease inhibition found mostly in products with high volatilization and loss of nitrogen by evaporation of NO_2, probability such as urea. Controlled release fertilizers are usually coated with one of the available coating materials, sulphur, polymers or a mix, in order to provide protection from water penetration in order to control the dissolution rate (Trenkel, 2020). Variation of the quantity applied at side-dressing is an important factor as quantities of N used at side-dressing might be to high depending on the type of N fertilizer used.

For the purpose of our study we have used the inbred lines of simple hybrid P9889. This hybrid is a medium maturity FAO 350 hybrid with several important agronomic traits such as a high stay green which allows better use of available soil humidity in later stages of vegetation (Aquamax), good adaptability to the soil and climatic conditions in NE Romania and good drought tolerance. Seed developer provides planting instructions on a yearly basis, with recommended planting parity 6:2 distance between rows is 60 cm. Female inbred with the first male inbred are planted first and then the second male inbred is planted after 33 GDD (Growing Degree Days) in order to have better dispersion of pollen and flowering time and improve nicking percentages. 6:2 planting ratios are desired by farmers as they are less complicated and costly to achieve technically compared to other complex ones, and at the same time the surface of female plants, which will be harvested, per hectare is higher (75%) compared to classical ratios such as 4:2 (67%) (Sirih et al., 2021). The size of each variant of the study was 192 m^2, which is the product of the width of 8 rows of plants with 60 cm spacing between then and 40 m the length of a variant.

Distance between seeds per row has been set at 18.3 cm which determines a high female density in the field.

The first year of field experience (2020), was a very dry and warm year, with an average temperature of 12.5°C, the highest value on record. In terms of precipitation, the average level of 479.9 mm of rainfall was under the yearly average of 510 mm, and at the same very concentrated in the early maize growing season, with most of the precipitation in May and early June of 222.4 mm, after which there was a severely dry period with 62.5 mm of precipitation from July to September (Weatherspark, 2020).

For 2021 we could observe very favorable climatic conditions for maize production with parameters such as average temperature of 10.6°C, near the last 10-year average. Precipitations quantity wise and in terms of dispersion were exceptional 564.6 mm, above multi-year average 510 mm, with 390.3 mm between April-August (Weatherspark, 2021).

The year 2022 was in the middle in term of average temperatures as yearly average was 11.8°C well above the mean average for the past 30 years 10°C, but in terms of precipitation it has been the driest on record with 399.7 mm a dramatic decrease from yearly averages of 510 mm for the area. The dispersion of precipitation was very unfavorable for maize growing as during the period May-July total precipitation was 85 mm (Weatherspark, 2022).

In order to quantify and evaluate the effects of the factors under study we adopted an integrated approach combining essential phenotypic elements with yielding elements:

- plant height at flowering (before detasseling);
- number of leaves per plant at detasseling;
- number of grains/row;
- flowering gap between male 1 and female inbreds (days);
- seed yield (kg/ha).

Analysis of the primary data collected was performed using statistical tools such as ANOVA analysis, linear regression in order to identify possible relationships between factors and determined elements. In order to identify the best option for practice in large farms, by comparing different variants with each other and the control variant, additional statistical tests, such as Fisher's, Tuckey's and Dunnett's test, were performed (Stanley, 2013).

RESULTS AND DISCUSSION

The results of our research show that in the conditions of our test plots new types of fertilizer perform in a similar way with classical ones with no negative effect on hybrid seed yield. Each variant tested has outperformed the control variant, classical, slow release and controlled release fertilizers in terms of yield by at least 832 kg/ha, which for hybrid seed is a consistent increase (Table 2). We can observe an increase in yield of 1720 kg/ha in the case of classical fertilizer ammonium nitrate at the rate of 80 kg/ha the top performing variant.

Table 2. Hybrid seed yield results according to nitrogen fertilizer applied sidedressing

Experimental variants	Nitrogen fertilizer applied sidedressing		Hybrid seed yield (kg/ha)				Average difference to Control (kg/ha)
	Fertilizer product	Nitrogen rate (kg/ha)	2020	2021	2022	Average	
a0b0	-	0	7463	7683	6583	7243	Control
a1b1	Ammonium nitrate	40	8700	8930	6627	8086	843
a1b2	Urea	40	8900	9120	7032	8351	1108
a1b3	Urea NG	40	9000	9220	7038	8419	1176
a1b4	Multicote (4) 34-0-7	40	8850	9080	6913	8281	1038
a2b1	Ammonium nitrate	80	9563	9793	7532	8963	1720
a2b2	Urea	80	9475	9695	7324	8831	1588
a2b3	Urea NG	80	9538	9758	7211	8836	1593
a2b4	Multicote (4) 34-0-7	80	8975	9205	6928	8369	1128
a3b1	Ammonium nitrate	120	8863	9093	6961	8306	1063
a3b2	Urea	120	9375	9595	7062	8677	1434
a3b3	Urea NG	120	9438	9658	7063	8720	1477
a3b4	Multicote (4) 34-0-7	120	9538	9768	7223	8843	1600

Determinations relevant to our study were performed starting at planting time to evaluate plant development until application of nitrogen at sidedressing in order to ensure that there were no anomalies in term of development compared to the control. After sidedressing application of nitrogen at different rates we observed that foliar development was increased with an extra leaf for top performing variants: ammonium nitrate with 80 kg/ha nitrogen, urea NG with 80 kg/ha nitrogen and Multicote (4) 34-0-7 with 120 kg/ha nitrogen (Table 3). A well-developed foliar system is essential in hybrid seed maize production as each leaf above the cob left after detasseling is a 300 kg of seed production.

This is consistent with the curve of solubilization of these 3 different types of fertilizer. As the classical and slow-release fertilizers are available faster for plant uptake compared to controlled release fertilizers, thus need to increase the quantity of nitrogen in order to obtain similar yield results.

Plant height varied, in average for the three years of research, from 202 cm in the case of ammonium nitrate with the nitrogen rate of 80 kg/ha to 182 cm in the case of the control variant (Table 3). This is putting into evidence the effect of nitrogen applied during the high growth period starting at BBCH-18 with the classical fertilizer variant, with more readily available nitrogen, especially in drought conditions.

We know through research that if the number of maximum rows of the cob is set by BBCH-18, and thus unaffected by our study, the number of grains per row is established until BBCH-24 (Nielsen, 2007) and such is impacted by the factors of our study. We could observe that the best performing variant with the nitrogen rate of 80 kg/ha from ammonium nitrate generated 1-2 more kernels per row, which results in a significant increase in yield (Table 4).

The flowering gap between inbreds is an issue of concern when producing hybrid maize seed due to the need of nicking at time of pollination in order to obtain well pollinated cobs. Our observations have put into evidence hat the gap between male inbred anthers opening and female silk emergence was 3-4 days which is consistent with what was scheduled at planting time and in line with protandric effects seen during drought time in maize (Table 4).

Coefficient of correlation (R^2) values of over 0.3 in the case of our fertilization shows that there is an important impact of our factors in hybrid seed yields, even though there are many technological aspects which can impact final production (Table 5).

Table 3. Maize plant height and number of leaves per plant according to nitrogen fertilizer applied sidedressing

Experimental variants	Nitrogen fertilizer applied sidedressing		Plant height at detasseling (cm)				Number of leaves at detasseling			
	Fertilizer product	Nitrogen rate (kg/ha)	2020	2021	2022	Average	2020	2021	2022	Average
a0b0 - Control	-	0	181	188	176	182	15	16	14	15
a1b1	Ammonium nitrate	40	184	192	177	184	15	16	15	15
a1b2	Urea	40	189	197	179	188	16	17	14	16
a1b3	Urea NG	40	186	195	178	186	16	17	15	16
a1b4	Multicote (4) 34-0-7	40	186	194	178	186	15	17	14	15
a2b1	Ammonium nitrate	80	203	210	192	202	17	18	16	17
a2b2	Urea	80	196	203	189	196	16	18	15	16
a2b3	Urea NG	80	198	206	190	198	17	18	16	17
a2b4	Multicote (4) 34-0-7	80	187	195	180	187	16	17	15	16
a3b1	Ammonium nitrate	120	186	196	177	186	15	18	14	16
a3b2	Urea	120	192	199	183	191	16	18	14	16
a3b3	Urea NG	120	194	200	186	193	15	18	15	16
a3b4	Multicote (4) 34-0-7	120	195	203	188	195	17	18	16	17

Table 4. Flowering gap and number of grains per row according to nitrogen fertilizer applied sidedressing

Experimental variants	Nitrogen fertilizer applied sidedressing		Flowering Gap (days)				Number of grains per row			
	Fertilizer product	Nitrogen rate (kg/ha)	2020	2021	2022	Average	2020	2021	2022	Average
a0b0 - Control	-	0	4	3	4	4	15	17	15	16
a1b1	Ammonium nitrate	40	4	4	5	4	16	18	15	16
a1b2	Urea	40	4	4	5	4	16	19	15	17
a1b3	Urea NG	40	4	4	5	4	16	19	15	17
a1b4	Multicote (4) 34-0-7	40	4	4	5	4	16	19	15	17
a2b1	Ammonium nitrate	80	3	3	4	3	18	20	17	18
a2b2	Urea	80	4	3	4	4	17	19	16	17
a2b3	Urea NG	80	3	3	4	3	18	20	17	18
a2b4	Multicote (4) 34-0-7	80	4	4	5	4	16	18	16	17
a3b1	Ammonium nitrate	120	4	4	5	4	17	19	14	17
a3b2	Urea	120	4	3	5	4	17	20	15	17
a3b3	Urea NG	120	4	3	4	4	17	20	15	17
a3b4	Multicote (4) 34-0-7	120	3	3	4	3	18	20	17	18

Table 5. R squared value of regression

Goodness of fit statistics (Yield):	
Observations	52
Sum of weights	52
DF	39
R^2	0.304

The distribution of yield obtained per each variants shows a slightly increasing trend for the types of fertilizer and different rates used, all being more productive than the control (Figure 1). If we analyze the pattern of the distribution we observe 3 variants which seem to outperform the main trend line: 80 kg/ha of nitrogen from ammonium nitrate, 120 kg/ha of nitrogen from Multicote 34-0-7 and 80 kg/ha of nitrogen from Urea NG. Thus, all 3 types of fertilizer (classic, slow-release and controlled release) at different rates produce similar yield.

Following our statistical analysis process, we can outline the fact that slow-release and controlled release fertilizers do not adversely impact yield and phenotypical development of the plant if used at required rates. We could see that 80 kg/ha of nitrogen from urea NG and 120 kg/ha of nitrogen from Multicote (4) 34-0-7 produce similar results as classical fertilizers. Possible adjustments of the moment of application could lead to the conclusion that it is more economically fructuous to remove the necessity of the extra pass for fertilization and cultivation.

By using the Tukey Test (Table 6) we demonstrated, by analyzing if differences between variants are significant, that controlled release, slow release and classic fertilizers applied at certain rates can obtain similar yields. This test also shows us that the optimum for maize hybrid seed production with sidedressing of nitrogen is using 80 kg/ha from ammonium nitrate.

Using the Dunnett test in sequence with Tukey test confirms that there is no significant difference between the 3 types of fertilizers in terms of yield when using certain rates of application (Table 7).

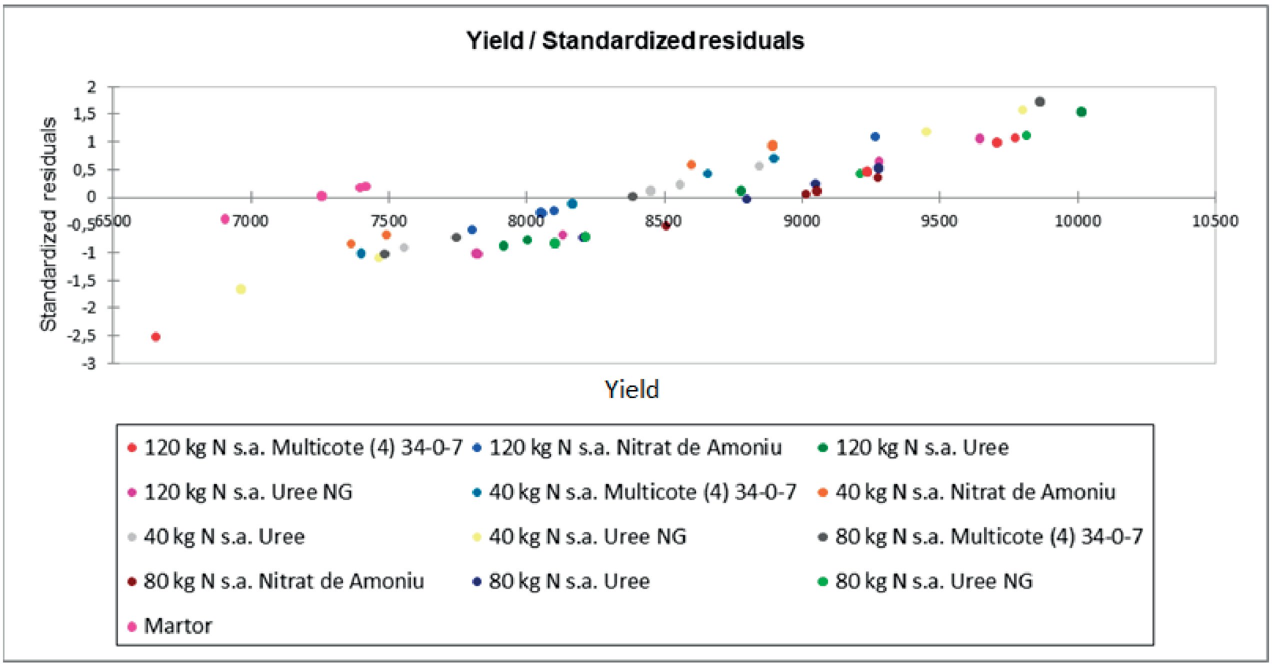

Figure 1: Yield distribution of variants

Table 6. Tukey Test group

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups
80 kg N a.s. Ammonium Nitrate	8962.178	435.450	8081.397	9842.959	A
120 kg N a.s. Multicote (4) 34-0-7	8842.739	435.450	7961.958	9723.520	A
80 kg N a.s. Urea NG	8835.387	435.450	7954.606	9716.168	A
80 kg N a.s. Urea	8831.427	435.450	7950.647	9712.208	A
120 kg N a.s. Urea NG	8718.847	435.450	7838.066	9599.628	A
120 kg N a.s. Urea	8677.206	435.450	7796.425	9557.987	A
40 kg N a.s. Urea NG	8419.354	435.450	7538.573	9300.134	A
80 kg N a.s. Multicote (4) 34-0-7	8369.146	435.450	7488.365	9249.927	A
40 kg N a.s. Urea	8350.622	435.450	7469.841	9231.403	A
120 kg N a.s. Ammonium Nitrate	8305.387	435.450	7424.606	9186.168	A
40 kg N a.s. Multicote (4) 34-0-7	8280.825	435.450	7400.044	9161.606	A
40 kg N a.s. Ammonium Nitrate	8086.481	435.450	7205.701	8967.262	A
Control	7242.604	435.450	6361.823	8123.385	A

Table 7. Dunnett Test significance results

Contrast	Difference	Standardized difference	Critical value	Critical difference	Pr > Diff
Control vs 80 kg N a.s. Ammonium Nitrate	-1719.573	-2.792	2.905	1789.139	0.065
Control vs 120 kg N a.s. Multicote (4) 34-0-7	-1600.135	-2.598	2.905	1789.139	0.100
Control vs 80 kg N a.s. Urea NG	-1592.783	-2.586	2.905	1789.139	0.103
Control vs 80 kg N a.s. Urea NG	-1588.823	-2.580	2.905	1789.139	0.104
Control vs 120 kg N a.s. Urea NG	-1476.243	-2.397	2.905	1789.139	0.153
Control vs 120 kg N a.s. Urea	-1434.602	-2.330	2.905	1789.139	0.175
Control vs 40 kg N a.s. Urea NG	-1176.749	-1.911	2.905	1789.139	0.370
Control vs 80 kg N a.s. Multicote (4) 34-0-7	-1126.542	-1.829	2.905	1789.139	0.421
Control vs 40 kg N a.s. Urea	-1108.018	-1.799	2.905	1789.139	0.440
Control vs 120 kg N a.s. Ammonium Nitrate	-1062.783	-1.726	2.905	1789.139	0.489
Control vs 40 kg N a.s. Multicote (4) 34-0-7	-1038.221	-1.686	2.905	1789.139	0.517
Control vs 40 kg N a.s. Ammonium Nitrate	-843.877	-1.370	2.905	1789.139	0.745

By performing this research over 3 years we were able to study in a dynamic setting of climatic conditions the effect of the two studied factors on quantitative and qualitative components such as foliar development, yield elements, the flowering time gap between studied maize inbred lines. We could observe that for each determination of interest both classical and newer types of fertilizer perform similarly in cases which nitrogen release lag is taken into account. Economically due to the lower quantity of classical nitrogen fertilizers needed to achieve top yields they represent the best option for similar if not better results.

CONCLUSIONS

The results of the research over 3 years of different types of nitrogen fertilizer (classical, slow release and controlled release) applied at different rates at side-dressing (40, 80, 120 kg/ha) showed that even though new fertilizers have indeed a slower rate of disposition of nitrogen towards the plant, at side-dressing they are not, in terms of yield, the best solution. Classical fertilizers applied at BBCH-18 still offer the best return in terms of yield, as newer fertilizers dispose of the main part of their nitrogen content later that needed by the plant, thus they are a behind the curve of consumption. In terms of plant development and hybrid maize seed production newer fertilizers perform at the same level as classical ones. The most efficient option to sidedress maize with nitrogen is using 80 kg/ha from ammonium nitrate which ensures the highest yield of hybrid maize seed at the best cost, as classical fertilizers are cheaper than newer types of fertilizer.

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