Scientific Papers. Series A. Agronomy, Vol. LXV, No. 2, 2022
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

RESULTS REGARDING THE EFFECT OF MICROGRANULATED FERTILIZERS IN HYBRID SEED MAIZE PRODUCTION

Lucian-Constantin HARAGA, Lizica SZILAGYI, Viorel ION

University of Agronomic Sciences and Veterinary Medicine of Bucharest,
59 Marasti Blvd, 011464, District 1, Bucharest, Romania

Corresponding author email: haragalucian@yahoo.com

Abstract

Maize is the cereal with the highest research and development budgets in the world, due to its high ecological distribution and to its vital role in human consumption and animal feeding. In the farms specialised in maize hybrid seeds production, there is a need to have increasing yields of hybrid seeds in view to be more and more efficient. But, having higher yields of hybrid seed cannot happen without the development of new fertilization strategies by farmers that multiply the seeds. Microgranulated fertilizers have been gaining an increasingly important role in these strategies due to the need to have a good development of the plants in the early growth stages. In this respect, our research aimed to study the effect of different microgranulated fertilizers on the yielding components and hybrid seed yield as well as on the overall development of the maize plants through their growth stages. The obtained results showed the following key aspects regarding the effects of microgranulated fertilizers: a better emergence of the plants in the field; a superior development of the root system and even better development where phosphorus concentrations used were higher; a better development of the leaves measurable until BBCH 18; no negative effects on nicking at pollination; increased TGW; improvement of hybrid seed yield in conditions of severe drought.

Key words*: maize, microgranulated fertilizers, hybrid seed yield, yielding components.*

INTRODUCTION

Increasing crop yields has been the foremost objective of research and practice in agriculture, as the XXth century was the start of a demographic boom which continues at an accelerated pace in the XXIth century, in order to be able to sustain the increasing number of people living on earth with limited arable land resources.

According to FAO data, the maize harvested area increased continuously since 1961, exceeding for the first time the area of 200 million ha in 2020 (201.98 million ha), maize ranking the second place in the world as harvested area, after wheat. This vast increases of land cultivated worldwide with maize raises the demand for quality maize seed in order to be able to attain higher yields.

The primary aim of an effective seed production programme is to supply adequate quantities of high quality seeds to farmers at the right time and place (Ibrahim, 2010). Therefore, new developments in technology that mitigates limitative factors of production are firstly adopted by farmers that multiply seeds for big agribusiness companies with high R & D potential. This is explained by the pressure the seed companies apply on farmers, and by the incentive of the extra premium obtained by increasing yield. Hybrid maize seed multiplication is a complex process that requires a close attention to the timing of planting the parental inbred lines to ensure the coincidence of flowering time, to removal of tassels from the female rows of plants before pollen shedding and to eliminate male rows of plants after pollination, all in order to harvest high quality hybrid seeds from the female plants.

A crucial yield limitation factor is fertilization, respectively plant nutrition, which has to sustain increasingly high potential hybrids by providing enough nutrients at precise moments in time (Jeffrey et al., 2003). Classical fertilization with 1:1:1 type fertilizers or 1:1:0 at planting or before seedbed preparation has been part of hybrid seed maize production since the introduction of hybrid seed in Romania in the 1960’s. Significant increases in the cost of fertilizer over the past years make it necessary to have a "minimum quantity-maximum effect" strategy, thus making it essential to place the fertilizer granules as close to the root system as possible to minimize unused fertilizer.

In contrast to DAP and other fertilizers, which are applied as a fertilizer band at a distance of around 10 cm to the seed, microgranulated fertilizer is ideally put in the soil together with the seed, at a distance of a few centimetres (Thielicke et al., 2022). Microgranulated fertilizers appeared as a starter fertilizer option to be placed as close as possible to the grain at planting time, based on the argument that a good root development of the seedling, helped by the high phosphorus content of the microgranules, is key for a good growing of the maize plants and will therefore impact in the end the yield (Lemarchand et al., 2016).

The principle is based on the fact that as soon as imbibition of the seed starts also the solubilisation of the microgranules begin, thus the first elements of the root system will develop in a medium rich in phosphorus, nitrate and zinc helping it to develop more quickly. This type of fertilizer available on the market is usually differentiated by the content of P_2O_5 and nutrients such as zinc and sulphur. The small content of Zinc in the fertilizer formulation helps especially in soils with low P_2O_5 content (<15 ppm) where usually it can observe zinc deficiency (Brady & Weil, 2008) especially in monoculture conditions.

In seed production, the use of microgranulated fertilizers raises questions about whether there is any differential effect on the two parental lines used in the maize crossing process, if there is a different root development, general phenotypic development, flowering time differences, and not the least, yield differences. The aim of this study was to evaluate all these possible effects of microgranulated fertilizer on maize inbred lines, in this case the hybrid P9889, under different fertilization situations.

MATHERIALS AND METHODS

Field experiments were conducted in 2020 and 2021 on a chernozem soil in the north-eastern part of Romania, respectively in the pedo-climatic conditions of the Moldavian Plain near the Prut River in Bivolari commune, Iasi County, on the land of the economical entity Semconsult Top SRL.

Tested variants in the field trails were based on different types of microgranulated fertilizer with different contents of P_2O_5, compared with two controls one being the classical fertilization scheme of the farmer approved by a quality control specialist of the hybrid's parent company.

The field experience was based on the method of subdivided plots with 4 replications being of type 2 x 4 with the following factors (Table 1):

- Factor A - base fertilization, with 2 graduations:
  - a1 = fertilization at seedbed preparation;
  - a2 = fertilization at seedbed preparation + nitrogen application in the growth stage of the maize plants BBCH 18;
- Factor B - microgranulated fertilizer, with 4 graduations:
  - b0 = no microgranulated fertilizer;
  - b1 = Physiostart microgranulated fertilizer;
  - b2 = Greenstart microgranulated fertilizer;
  - b3 = Pannon Starter microgranulated fertilizer.

The microgranulated fertilizers used stimulates root development by providing easily assimilable phosphorus, ensuring a quick start to the crop. Nitrogen and phosphorus support strong rooting and the development of a rich and healthy foliage (Stanley & Rhoads, 1977). Microelements stimulate the metabolic and hormonal activity of plants and support generation of the necessary content of chlorophyll.

The content of nutrients in microgranules cannot replace the nutrition provided by classic fertilizers, they only augmenting the base fertilization scheme. Therefore, it was important to include base fertilization in our experiments.

In the field experiments, there was used the inbred lines of hybrid P9889, a FAO 350 hybrid with good drought tolerance, stay green effect and well suited for the climate and soil conditions found in the Moldavian plain. The planting instructions by the seed developer recommended a parity of 6:2 with 60 cm between rows, planting the Female and Male 1 first and then Male 2 after 33 GDD in order to ensure better flowering synchronisation and a longer pollen coverage time. The 6:2 ratios of female to male rows are less complicated and less costly to handle with conventional planters and harvesters (Wright, 1980).

The experimental variant had 192 m^2 size which resulted from 8 row plants (6 female rows and 2 male rows) with 60 cm between rows meaning 4.8 m and 40 m length.

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
a1b0	Ammonium nitrate	Autumn (preceding year)	100	33.5	0	0	0	0	0	0
	14:14:14+7SO+4MgO	Seedbed preparation	300	42	42	42	21	12	0	0
	20:20:0+0.5Zn	Seedbed preparation	150	30	30	0	0	0	0	0.75
	Total - a1b0			*105.5*	*72*	*42*	*21*	*12*	*0*	*0.75*
a1b1	a1b0 + Physiostart	Sowing	20	1.6	5.6	0	4.6	0	2.8	0.4
	Total - a1b0 + Physiostart			*107.1*	*77.6*	*42*	*25.6*	*12*	*2.8*	*1.15*
a1b2	a1b0 + Greenstart	Sowing	20	3.2	8	0	1	0.4	0	0.4
	Total - a1b0 + Greenstart			*108.7*	*80*	*42*	*22*	*12.4*	*0*	*1.15*
a1b3	a1b0 + Pannon Starter	Sowing	20	1.8	8	0	1	0	0	0.2
	Total - a1b0 + Pannon Starter			*107.3*	*80*	*42*	*22*	*12*	*0*	*0.95*
a2b0	Ammonium nitrate	Autumn (preceding year)	100	33.5	0	0	0	0	0	0
	14:14:14+7SO+4MgO	Seedbed preparation	300	42	42	42	21	12	0	0
	20:20:0+0.5Zn	Seedbed preparation	150	30	30	0	0	0	0	0.75
	Ammonium nitrate	BBCH 1.6	200	67	0	0	0	0	0	0
	Total - a2b0			*172.5*	*72*	*42*	*21*	*12*	*0*	*0.75*
a2b1	a2b0 + Physiostart	Sowing	20	1.6	5.6	0	4.6	0	2.8	0.4
	Total - a2b0 + Physiostart			*174.1*	*77.6*	*42*	*25.6*	*12*	*2.8*	*1.15*
a2b2	a2b0 + Greenstart	Sowing	20	3.2	8	0	1	0.4	0	0.4
	Total - a2b0 + Greenstart			*175.7*	*80*	*42*	*22*	*12.4*	*0*	*1.15*
a2b3	a2b0 + Pannon Starter	Sowing	20	1.8	8	0	1	0	0	0.2
	Total - a2b0 + Pannon Starter			174.3	*80*	*42*	*22*	*12*	*0*	*0.95*

The sowing distance between seeds were of 18.3 cm, ensures thus high female crop density.

The year 2020 can be characterised as being a warm and dry one, with an average temperature of 12.5°C which was the highest registered ever, and with 479.9 mm rainfall very unevenly distributed, with 1.8 mm in April and 5.8 mm in August, but with 132 mm in May and 90.4 mm in June.

The year 2021 can be characterised as being a favourable one for maize crop, with an average temperature of 10.6°C and 564.6 mm rainfall among which 390.3 mm in period April-August.

Core phenotypic and yielding elements determined and studied in the field and laboratory were the following:

- Plant height - at 8-leaf stage (BBCH 18);
- The number of leaves per plant;
- Evolution of the root system up to the phase of 4 and 8 leaves (BBCH 14 and BBCH 18);
- Duration from sowing (BBCH 00) to emergence (BBCH 09) and from emergence (BBCH 09) to flowering (BBCH 51);
- The flowering time gap between male inbred and the female inbred;
- Hybrid grain yield/ha;
- Yielding components: length of the cob; number of rows/cob; number of kernels/cob; thousand grain weight (TGW).

Statistical analysis was performed using the ANOVA analysis and linear regression in order to determine the relationships between different traits. Specific tests such as Fisher's test, Tukey's test and Dunnett's were also used to compare the different variants with each other and to the 2 control variants.

RESULTS AND DISCUSSIONS

The results revealed a significant correlation between all analysed characters and the hybrid seed yield. For each comparison the fertilized version of the microgranulated fertilizer, the products used have outperformed the control variant. Thus, there was a yield increase over the 2 years of 1188 kg compared to the control variant 1 and 300 kg when compared to the control variant 2 in the case of high P_2O_5 microgranulated fertilisers (Table 2).

Relevant observations were made starting from the first phases of plant development, time for emergence of the plants that had microgranulated applied at sowing being smaller than for the control group by 1-3 days, according to the climatic conditions of the year (Table 3).

It can be extrapolated that the existence of available phosphorus content near the seed helped increase the speed of seedling

development thus leading to a much faster emergence.
Another important evaluation stage was the 4 leaf stage (the latest for early post-emergence herbicide application) where the development of the root system of the high phosphorus microgranulated variant has been more developed than the control variant, and the medium phosphorus microgranulated variant, i.e. 8-9 roots vs 5-6 and vs 6 roots (Table 3).
Before cultivation, at 8 leaf-stage, it was evaluated again the development of the root system and the difference observed at the 4 leaf-stage evaluated had increased to 10-11 roots vs 6-7 and vs 8-9 roots (Table 3).

Table 2. Hybrid seed yield results

Experimental factors	Fertilizer products and their rates	Hybrid seed yield (kg/ha)			Difference to Control 1	Difference to Control 2
		2020	2021	Average		
a1b0 Control 1	Ammonium nitrate - 100 kg/ha 14:14:14+7SO+4MgO - 300 kg/ha 20:20:0+0.5Zn - 150 kg/ha	8405	8625	8515	Control	-
a2b0 Control 2	Ammonium nitrate - 100 kg/ha 14:14:14+7SO+4MgO - 300 kg/ha 20:20:0+0.5Zn - 150 kg/ha Ammonium nitrate - 200 kg/ha	9588	9818	9702.5	1188	Control
a1b1	a1b0 + Physiostart - 20 kg/ha	9075	9295	9185	670	-518
a1b2	a1b0 + Greenstart - 20 kg/ha	9750	9980	9865	1350	163
a1b3	a1b0 + Pannon Starter - 20 kg/ha	9675	9895	9785	1270	83
a2b1	a2b0 + Physiostart - 20 kg/ha	9050	9280	9165	650	-538
a2b2	a2b0 + Greenstart - 20 kg/ha	9850	10070	9960	1445	258
a2b3	a2b0 + Pannon Starter - 20 kg/ha	9875	10105	9990	1475	288

Table 3. Experimental observations

Experimental factors	Fertilizer products and their rates	Time to emergency			No of root at BBCH-14			No of root at BBCH-18			Days between Male 1 and Female flowering		
		2020	2021	Average	2020	2021	Average	2020	2021	Average	2020	2021	Average
a1b0 Control 1	Ammonium nitrate – 100 kg/ha 14:14:14+7SO+4MgO – 300 kg/ha 20:20:0+0.5Zn - 150 kg/ha	8	9	8.5	5	6	5.5	6	7	6.5	5	3	4
a2b0 Control 2	Ammonium nitrate – 100 kg/ha 14:14:14+7SO+4MgO – 300 kg/ha 20:20:0+0.5Zn - 150 kg/ha Ammonium nitrate – 200 kg/ha	8	9	8.5	5	6	5.5	6	7	6.5	4	3	3.5
a1b1	a1b0+Physiostart-20 kg/ha	8	7	7.5	6	6	6	8	9	8.5	4	3	3.5
a1b2	a1b0+Greenstart-20 kg/ha	7	6	6.5	8	9	8.5	10	11	10.5	3	2	2.5
a1b3	a1b0+Pannon Starter - 20 kg/ha	7	6	6.5	8	9	8.5	10	11	10.5	3	2	2.5
a2b1	a2b0+Physiostart-20 kg/ha	8	7	7.5	6	6	6	8	9	8.5	3	3	3
a2b2	a2b0+Greenstart-20 kg/ha	7	6	6.5	8	9	8.5	10	11	10.5	3	2	2.5
a2b3	a2b0+Pannon Starter 20 kg/ha	7	6	6.5	8	9	8.5	10	11	10.5	3	2	2.5

The number of roots are positively correlated with the final hybrid seed yield. Another key period for maize hybrid production is flowering time, which has a great impact in the final yield. The time gap between the opening of male anthers to release pollen and the emergence of female silks is an optimum of 2-3 days. In case of both types of microgranulated fertilizers, high P_2O_5 and medium P_2O_5, there was no ill effects on this gap, which was one of the questions of the study as we have in the plots both male and female plants which could react differently to fertilization. It was observed that pollen shedding was 3-5 days before silking in 2020, as drought had a protandric effect on the plants, but in 2021 pollen release started perfectly at 2-3 days before silking. The high phosphorus microgranulated fertilisers had a better effect on the gap between the opening of male anthers and the emergence of female silks, this being of 2-3 days compared to 3-5 days for control variants and 3-4 days for the medium phosphorus fertilisers (Table 3).

The value of R squared > 0.6 shows us that there is a good positive link between hybrid seed yield and the use of microgranulated fertilizers (Figure 1).

The results of the statistical analysis performed shows very strong positive correlations, for both types of microgranulated fertilizers, between yielding elements. Thus, the length of the cob, number of grains on the cob, number of rows per cob, and TGW, all these yielding elements are higher compared to the control variants. We can say that the faster start of the plants helped to have a harmonious vegetative development which helped to sustain better the generative phase of the plants life and thus the development of productive elements.

The results of the Tukey Test (Table 5) performed, which shows if differences between variants are significant, demonstrate that the microgranulated fertilizers with a higher content of P_2O_5 (>=40%) are providing a statistically significant yield, these being a distinct Group A in the output of Tukey testing, increase versus the 2 control variants.

Dunnett test confirms the results that all microgranulates with high phosphorus content determine statistically significant increases of yield (Table 6).

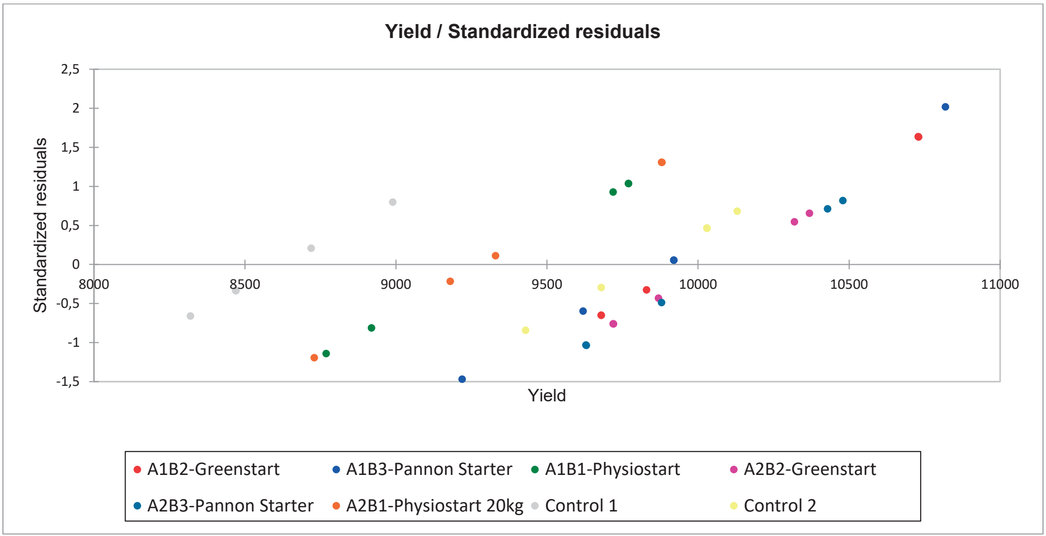

Figure 1. Yield distribution of variants

Table 4. R squared value of regression

Goodness of fit statistics (Yield):	
Observations	32
Sum of weights	32
DF	24
R^2	0.599

Table 5. Tukey Test groupings

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups	
A2B3-Pannon Starter	10105.000	229.553	9631.226	10578.774	A	
A2B2-Greenstart	10070.000	229.553	9596.226	10543.774	A	
A1B2-Greenstart	9980.000	229.553	9506.226	10453.774	A	
A1B3-Pannon Starter 20kg	9895.000	229.553	9421.226	10368.774	A	
Control 2	9817.500	229.553	9343.726	10291.274	A	
A1B1-Physiostart 20kg	9295.000	229.553	8821.226	9768.774	A	B
A2B1-Physiostart 20kg	9280.000	229.553	8806.226	9753.774	A	B
Control 1	8625.000	229.553	8151.226	9098.774		B

Table 6. Dunnett Test significance results

Contrast	Difference	Standardized difference	Critical value	Critical difference	Pr > Diff	Significant
Control 1 vs A2B3-Pannon Starter	-1480.000	-4.559	2.814	913.620	0.001	Yes
Control 1 vs A2B2-Greenstart	-1445.000	-4.451	2.814	913.620	0.001	Yes
Control 1 vs A1B2-Greenstart	-1355.000	-4.174	2.814	913.620	0.002	Yes
Control 1 vs A1B3-Pannon Starter	-1270.000	-3.912	2.814	913.620	0.004	Yes
Control 1 vs Control 2	-1192.500	-3.673	2.814	913.620	0.007	Yes
Control 1 vs A1B1-Physiostart	-670.000	-2.064	2.814	913.620	0.220	No
Control 1 vs A2B1-Physiostart	-655.000	-2.018	2.814	913.620	0.238	No

The study allowed us to efficiently highlight and observe all the qualitative and quantitative components such as early root, foliar, and yielding elements development together with flowering time gap, and have a consistent direct impact, which are critical to yield development of hybrid seed maize. For each of these elements, variants fertilized with microgranulated fertilizer at sowing time have proven to perform better than the control variant, and the variants with higher P2O5 content even better.

CONCLUSIONS

The results of the performed researches show that, even though microgranulated fertilizers in seed maize production are not a key element, their use will help the overall development of the plant, the formation of the yielding elements and not the least the yield. This in the context of high economic value of the maize hybrid seeds makes the use of such fertilizers very efficient leading to higher revenues.

The most effective microgranulated fertilizers are the ones with a high content of P_2O_5 leading to a fast emergence and fast development until 8th leaf (BBCH 18). The root system develops faster and supports a very quick development of the maize plant, with a shorter time until flowering but with superior leaf area development.

AKNOWLEDGEMENTS

This research paper was supported by the Doctoral School of the University of Agronomic Sciences and Veterinary Medicine of Bucharest. We would like to thank Mr. Liviu Zbant, PhD agronomist engineer, Mr. Liviu Nicorici, PhD student, and agronomist engineer, and Mr. Alexandru Baghiu, agronomist engineer, for all their support in the field experience.

REFERENCES

Brady, N.C., Weil, R.R., (2008). Nature and Properties of Soils. Prentice-Hall, Inc., Upper Saddle River, New Jersey.

Ibrahim, U. (2010). Effect of Time of Planting and Fertilizer Application on Maize Seed Multiplication Ratio. *International Journal of Applied Agricultural Research, 5*(3), 309–315.

Jeffrey, A.V. and Gyles, W.R. (2003). Corn Production as Affected by Nitrogen Application Timming and Tillage. *Agronomy Journal. Published by American Society of Agronomy*, 502–509.

Lemarchand, L., Revellat, J., Benedetti, A. (2016). CVA Fertilizer Practice - Micro-Granular Fertilizers Market Study and Route-to-Market (www.corporatevalue.com).

Wright, H. (1980). Commercial Hybrid Seed Production. In Walter R. Fehr, Henry H. Hadley (Ed.), *Hybridization of Crop Plants* (161-176). American Society of Agronomy and Crop Science Society of America.

Stanley, R.L., Jr., and Rhoads, F.M. (1977). Effect of time, rate, and increment of applied fertilizer on nutrient uptake and yield of corn (*Zea mays* L.) *Proc. Soil Sci. Soc. Fla.*, *36*, 181–184.

Thielicke, M., Ahlborn, J., Zivotic, L., Saljnikov, E., Eulenstein, F. (2022). Microgranular fertilizer and biostimulants as alternatives to diammonium phosphate fertilizer in maize production on marshland soils in northwest Germany. *Zemljiste I Biljka, 71*(1), 53–66

https://www.fao.org/faostat/en/#data/QCL