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RESPONSE OF MAIZE (*Zea Mays* L.) GRAIN YIELD AND YIELD COMPONENTS TO INTEGRATED FERTILIZATION WITH GREEN MANURE AND NITROGEN

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Abstract

Green manures are an alternative to improve nitrogen availability for plant nutrition in a global context of declining soil fertility. To investigate the effects of green manure and nitrogen fertiliser on maize yield under the Braila Agricultural Development Research Station conditions, a bifactorial experiment with four replications was conducted for two years. The main factor was the use of green manures at four levels (control - without green mulch crop; winter pea (Pisum sativum L. var. arvense.); white mustard (Sinapis alba L); winter rye (Secale cereale L.), while the sub-factor was the application of N fertilizer at four levels (0, 60, 90 and 120 kg/ha of N active substance). Green manure application significantly influenced corn yield, with increases of 19.4% for winter pea, 16.9% for white mustard, and 9.8% for rye. The same significant influence was found on plant height and yield components. The application of different levels of nitrogen also had a very significant influence on yield results and yield components.

Key words**:** *maize, green manure crops, mineral fertilization*

INTRODUCTION

Maize is a significant worldwide commodity. It is used both as a direct food source and as an indirect feed for animal-sourced foods. The crop is highly adaptable and serves multiple purposes. Additionally, it has various non-food uses on a global scale. In recent decades, there has been a significant increase in global maize production. The global utilization of maize is projected to experience ongoing expansion. Currently, this grain holds the top position in terms of output volume and is projected to surpass all other crops in terms of cultivated area in the next ten years [8].

Romania has an internal use of fertilizers which cannot be covered in the coming years by domestic production and is dependent on the import of mineral fertilizers, and a solution may be to replace chemical fertilizers with natural fertilizers [3].

The application of mineral fertilizers leads to significant increases, but the unbalanced application of fertilizers chemical fertilizers can cause imbalances in the plant and yield increases be smaller as the amount applied increases above the useful limit [15].

Combining the application of organic and inorganic fertilizers appears to be a viable approach to address the crop's needs, enhance soil quality, and optimize nutrient usage efficiency. The correct timing and sequence of nitrogen application are crucial for its effective utilization [10].

Effective nitrogen fertilizer management plays a crucial role in agricultural activities, greatly enhancing crop output [6].

Nitrogen treatments improve the yield and quality of hybrid. Combining the utilization of urea with other manure tends to increase the yield and yield-related traits of maize hybrids. Higher yield performance of maize hybrids can be obtained by alternating mineral fertilizer with organic fertilizer to construct a more efficient farming cycle with an environmentally friendly or more sustainable system [10].

Research conducted by Boiko et al. (2024) between 2016 and 2022 showed that the highest yield in grain maize crops was obtained when an organo-mineral fertilization system

was used, with an 18% increase compared to the unfertilized control variant [5]

According to Delibaltova (2014), the value of yield structural elements and grain yield of the studied genotypes increased as the amounts of nitrogen fertilization increased. The application of 240 kg N/ha resulted in the highest recorded values for the maximum number of rows per cob, number of grains per row, number of grains per cob, length of cob, cob weight, the weight of grains per cob, and thousand-grain weights, compared to other rates [7].

Marković et al. (2017) reported that the impact of N fertilization on maize was statistically significant for all variables examined in both years of the research. The application of nitrogen fertilizer resulted in a significantly greater grain output compared to the control treatment in both growing seasons. The yield components, including length, grain weight per ear, number of grains per ear, and 1,000-grain weight, exhibit a considerable increase as the nitrogen rate is increased from 0 to 200 kg N/ ha [12].

There is increased interest in organic fertilizers due to high prices, unavailability, or limited supply of mineral fertilizers. The importance of the use of green manure also derives from the decreasing production of organic fertilizers due to decreasing livestock numbers. The application of mineral nitrogen in conjunction with organic fertilizers has led to increased yields and yield components [1] [2] [11].

Enhancing the sustainability of intensive agriculture relies on achieving a high grain yield while also maximizing nitrogen use efficiency in crop production. The incorporation of green manure along with a 30% reduction in chemical fertilizer resulted in a considerable decrease in nitrogen losses through volatilization and leaching, while yet maintaining a high yield of maize [9]. The superior efficacy of this management technique can be linked to the optimization of nitrogen supply and enhancement of maize nitrogen uptake through the synergistic utilization of green manure and reduction in mineral nitrogen application [4]

Su et al. (2022) also showed that when green manure is incorporated, total and available nitrogen and phosphorus increase significantly, allowing the nitrogen dose to be reduced by 11.2% [16].

The positive effects of organic fertilizers, even green manure, were particularly noticeable at lower N rates. Therefore, they should be used to reduce the application rate of inorganic fertilizers and the resulting environmental risks [17].

Therefore, this study aims to evaluate the efficacy of several types of green manure and levels of nitrogen fertilizer on maize yield and its components in Northeast Baragan conditions.

MATERIALS AND METHODS

Field experiment was carried out in the 2022 and 2023 growing seasons on vermic chernozem soil with a medium humus content of 2.4 - 3.1% in the upper horizons and only 1.6% in the transition horizon, 0.14-0.25 % total nitrogen content at the trial site of Agricultural Research and Development Station (ARDS) Braila - Chiscani Experimental Center.

The experiment was designed in fully randomized blocks with 4 replicates. The main plot factor was green manure (GM) species (control – without green manure crop; winter pea (*Pisum sativum* L. var. arvense); white mustard (*Sinapis alba* L); winter rye (*Secale cereale* L.).

The sub-factor was nitrogen fertilizer which was applied at four levels (0, 60, 90 and 120 kg/ha of N active substance). The size of each test plot was 42 m^2 and the total surface area of the research plot was 4,032 m^2.

Green manure cultivation was done in early September in the two years of testing. The green manure was chopped and incorporated into the soil according to species: mustard at the onset of winter, and winter pea and rye species were chopped and incorporated in the spring, about one month before corn sowing.

Mineral fertilization was carried out by administering a 15:15:15 complex NPK fertilizer at the same time as the seedbed preparation, and fractional doses of urea were applied during the maize growing season. Thus, N doses of 60, 90, and 120 kg/ha and an

agro-foundation of 40 kg/ha P and 40 kg/ha K were applied for all experimental variants.

Maize was sown on 04.05.2022 and 05.05.2023 with F423 hybrid at a density of 65,000 plants ha and harvesting was performed in the second decade of October in 2022 and 2023. During the growing season, weed and pest control treatments were applied and during the two years of experimentation, the maize was irrigated.

This paper's traits studied include plant height, grain yield and yield components. Plant height was determined in the field by biometric measurements on 10 plants from each experimental plot. For the determination of yield components, six ear for each experimental plot were analyzed.

The production was calculated after standardizing the moisture content of maize to 14%, which is the national standard of moisture content (STAS).

The statistical analyses of grain yield and yield component data included analysis of variance and Fisher's least significant differences test (LSD), using the Polifact statistical software [18].

Table 1. Rainfall regime from 2021 to 2023 at the ARDS Braila

Year/Months	Rainfall—Monthly Amount (mm)												Annual average
	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	
2021-2022	33	27	44	7	12	14	25	24	33	9	27	32	287
2022-2023	6	31	20	64	7	13	66	40	26	106	55	5	439
Multiannual average	30	33	36	28	27	26	35	48	62	46	39	32	442

Source: Meteorological Stations Braila [14].

Table 2. Thermal regime from 2021 to 2023 at the ARDS Braila

Year/Months	Temperature—Monthly Average (°C)												Annual average
	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	
2021-2022	10.2	8.1	2.5	1.3	4.1	3.8	11.9	18	22.7	24.8	24.9	17.9	12.5
2022-2023	13	8.1	2.9	4.4	1.4	7.9	10.4	16.6	21.6	24.7	24.7	20.9	13.1
Multiannual average	11.5	5.6	0.6	-2.1	-0.2	4.7	11.2	16.7	20.9	22.9	22.1	17.3	10.9

Source: Meteorological Stations Braila [14].

RESULTS AND DISCUSSIONS

ARDS Brăila is located in the eastern part of the Northern Bărăgan, in one of the driest agricultural areas in Romania. The territory of Northern Bărăganului de Nord, as indeed the entire area of the Romanian Plain, is characterized by a temperate continental climate. Summers are hot and dry; rainfall is low, heavy, and unevenly distributed. Climatic data in this paper come from the Meteorological Station of Brăila, located near the Experimental Center Chiscani. The multiannual temperature regime has an average value of 10.9°C, and the rainfall regime records an annual average of 442 mm.

In the crop year 2021-2022, the average temperature recorded was 12.5.°C. This was a warm year, with a deviation of the mean annual temperature of +1.6.°C from the multi-year average. In addition, it was an excessively dry year, with a negative deviation of 155 mm from normal in terms of precipitation.

The 2022-2023 crop year was very warm; the average temperature recorded was 13.1 .°C, with a positive deviation from the multi-year average of 2.2.°C. In terms of rainfall, it was close to normal, with 439 mm recorded, but with an uneven distribution of precipitation.

Plant height

In terms of morphological characteristics, hybrid Fundulea 423 is characterized as a vigorous plant, with an average height of 265 cm [13].

A comparison of means showed that the application of winter pea green manure increased plant height by 6.63%, a highly significant difference from the control, and

white mustard influenced plant height by 3.81%, a distinctly significant difference.
Winter rye had a significant negative influence on this parameter, reducing plant height by 2.94% (Table 3).
In addition, plant height also increased at the application of fertilizer levels with N. The highest plant height was observed in the 120 kg/ha N treatment, with a difference of 11% compared to the control.
The difference was highly significant as it was in the 90 kg/ha application rate.
The 60 kg/ha rate recorded a significant deviation from the control, but smaller compared to the other rates.
These results are due to the important role that green manures play in creating a nutrient space richer in organic matter, with also improved soil properties and increased nutrient availability.

Table 3. Effects of green manures and different nitrogen levels on maize. Average results 2022-2023

Treatment	Grain yield (kg/ha)	Plant height (cm)
Green manure levels		
Control (without green manure)	5,946	249.53
Winter pea	7,101***	256.16***
White mustard	6,952***	253.34**
Winter rye	6,530**	246.59º
	LSD (5%)= 375.26 kg/ha; LSD (1%)=521.09 kg/ha; LSD (0.1%)=728.21 kg/ha	LSD (5%)= 2.12 cm; LSD (1%)= 3.05 cm; LSD (0.1%)= 4.48 cm
Nitrogen levels		
Control (0)	5,946	246.84
60 kg/ha	6,388**	248.63*
90 kg/ha	6,989***	252.31***
120 kg/ha	7,856***	257.84***
	LSD (5%)= 298.52 kg/ha; LSD (1%)=399.79 kg/ha; LSD (0.1%)=527.26 kg/ha	LSD (5%)= 1.77 cm; LSD (1%)= 2.37 cm; LSD (0.1%)= 3.12 cm

Source: Own results.

Grain yield

Variance analysis indicates that green manure and nitrogen fertilizers influence maize yield significantly. Comparison of yield means highlights that the application of green manure winter pea increased the yield by 19.4% compared to the control variant; in the case of the application of green manure white mustard, the yield increased by 16.9%, and the application of rye as green fertilizer influenced the yield by 9.8% compared to control variant, statistically the differences were highly significant. The same result was demonstrated for the application of N doses, with increases of 7% for N60, 17.5% for N90, and 32.1% for N120.
Figure 1 shows the interactions between the nitrogen dose factor and the green manure factor, the differences were highly significant compared to the control. The most significant interaction was N120 x white mustard GM, with a yield of 10,022 kg/ha.

Grain weight

From the average results of the year 2022 and year 2023, the analysis of variance shows that the effects of green manure and nitrogen fertilizer on grain weight per cob were distinctly significant and highly significant compared to the control variant (Table 4). The average grain weight per cob was 5.8% higher for winter pea-GM and 3.7% and 3.2% higher for white mustard- GM and rye-GM, respectively, compared to the control variant. When applying nitrogen doses, the results were also statistically highly significant, with the highest difference given by the control with the highest nitrogen dose, N120, and the difference recorded was 16.2.

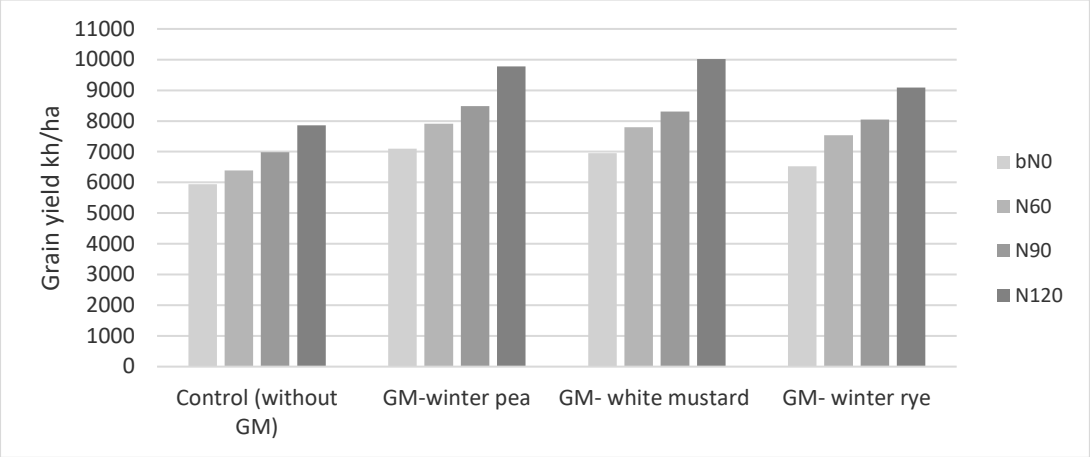

Fig. 1. The effect of nitrogen x green manure interaction on grain yield.
Average results 2022-2023.
Source: Own results.

Grain number/row

One of the most important components of yield is the number of grains per cob, which is affected by the plant's nutritional level. This indicator was very significantly influenced by the winter pea-GM application, significantly by the white mustard application, and insignificantly by the rye-GM application.

Cob length

Also, very significant differences were obtained for this indicator compared to the control version. For the application of green fertilizers, differences between 9.4-13% were obtained compared to the control, and for the application of nitrogen doses, differences between 2.2-7% were obtained.

Table 4. The effects of green manure and different nitrogen levels on yield components.Average results 2022-2023

Treatment	Grain weight (g)	Grain number/row	Cob length (cm)
Green manure levels			
Control (without green manure)	188.27	42.58	19.94
Winter pea	199.23***	44.47***	22.54***
White mustard	195.29**	43.49**	21.81***
Winter rye	194.36**	43.16⁻	21.87***
	LSD (5%)= 3.91 g; LSD (1%)=5.62 g ; LSD (0.1%)= 8.27 g	LSD (5%)= 0.83 ; LSD (1%)= 1.19; LSD (0.1%)= 1.75	LSD (5%)= 0.40 cm ; LSD (1%)= 0.58 cm; LSD (0.1%)= 0.85 cm
Nitrogen levels			
Control (0)	179.11	41.66	20.85
60 kg/ha	192.24***	43.36***	21.31**
90 kg/ha	197.65***	43.96***	21.68***
120 kg/ha	208.14***	44.72***	22.31***
	LSD (5%)= 4.27 g; LSD (1%)= 5.72 g; LSD (0.1%)=7.55 g	LSD (5%)= 0.47; LSD (1%)= 0.63; LSD (0.1%)= 0.84	LSD (5%)= 0.26 cm ; LSD (1%)= 0.35 cm; LSD (0.1%)= 0.47 cm

Source: Own results.

CONCLUSIONS

The results of this study demonstrate the potential of winter pea, white mustard, and rye species to be used as green manures in integrated fertilization schemes with mineral fertilizers in maize.

When considering mineral N, the most promising interactions were given by the combination of white mustard x 120 kg/ha N, which obtained a yield of 10,022 kg/ha, and the combination of winter pea x 120 kg/ha N, which obtained a yield of 9,778 kg/ha, however, compared to the control variant without green manure, all the integrated variants obtained significant yields.

Fertilization of green manure also influenced plant height, application of green manure of winter peas increased plant height by 6.63% and white mustard influenced plant height by

3.81%. Winter rye had a significant negative influence on this parameter, reducing plant height by 2.94%.

The yield components were also influenced. The average grain weight per cob was 5.8% higher for winter pea-GM and 3.7% and 3.2% higher for white mustard-GM and rye-GM, respectively, compared to the control. The number of kernels per row was highly significantly influenced by winter pea-GM, significantly by white mustard-GM, and insignificantly by rye-GM.

In terms of cob length, compared to the control variant, there were differences between 9.4-13%, and differences between 2.2-7% were obtained for the application of nitrogen doses.

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