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PRELIMINARY RESULTS OF INTEGRATED FERTILIZATION WITH GREEN MANURE AND MINERAL FERTILIZERS ON MAIZE YIELD

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Abstract

Maize (Zea mays L.) is an essential crop worldwide, and the application of fertilizers is a vital management strategy that significantly enhances its yield. The objective of this investigation was to assess the impact of green manure and mineral fertilization on the yield of maize. The experiments were conducted in an experimental field at Agricultural Research and Development Station Braila during the first decade of September 2021 to the second decade of October 2022. A bifactorial experiment was carried out based on the formula A × B, where A represents the green manure crops (a1– control – without green manure crop; a2- winter pea (Pisum sativum L. var. arvense); a3- white mustard (Sinapis alba L.); a4- winter rye (Secale cereale L.); a5- white mustard (Sinapis alba L) + rapeseed (Brassica napus L.); a6- rapeseed (Brassica napus L.) and B represents the mineral fertilization (b1– N0 unfertilized; b2- N60 (60 kg/ ha of N); b3- N90 (90 kg/ ha of N); b4- N120 (120 kg/ ha of N)). The results of this study show the benefits of integrated fertilization with green manure and mineral fertilizer. Maize grain yield was found to be enhanced by using green manure crops.

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

INTRODUCTION

With the increasing trend of global climate change, particularly as a result of drought stress, the growth, and yield of maize decrease dramatically around the world, particularly in arid and semi-arid regions. Organic and inorganic fertilizers can modify plants' morphological, physiological, and biochemical processes for improved adaptation to harsh environments [7].

Current methods for global food security mislead farmers into using the maximum amount of inputs (chemicals) for crop productivity. Green manure has evolved as a cost-effective alternative to artificially created chemical fertilizers for farmers fields. From germination to harvesting, green manure can fulfill of the physical, chemical, biological, and pathological needs of plants [1].

Green manuring is the process of incorporating or plowing green plants into the soil, whether they were grown in the field or elsewhere and were in the vegetative or flowering stages. Green manures are leguminous crops or forages that are grown to conserve soil by incorporating their leafy materials. Green manure crops are characterized by their short duration, rapid growth, and high production of organic matter, and as a result, they release nitrogen, phosphorus, potassium, and other plant nutrients. Through nodule formation in their roots, leguminous green manure plants are able to fix atmospheric nitrogen [11].

The decomposition of green manure crops releases nutrients and recycles nitrogen, phosphorus, and potassium in an integrated plant nutrition system [13].

Including green manure crops throughout the year in the crop rotation is a benefit where animal manures are limited. In addition to improving soil fertility, a green manure crop can reduce weed problems in annual staple crops following green manure crop periods [12].

Green manure crops offer a variety of benefits that can be broadly categorized as increased soil fertility. Green manures enrich the soil with organic matter and recycle nutrients. They prevent soil nutrients from being washed away. The green manure absorbs the nutrients and stores them within the plant. Legumes and other nitrogen-fixing plants are advantageous as they facilitate the transfer of nitrogen from the atmosphere to the soil. The principal advantage of utilizing green manure is its ability to serve as a source of nitrogen in instead of fertilizers. Green manures, particularly legumes, contain relatively more nitrogen, have a low carbon-nitrogen ratio, and behave almost identically to chemical nitrogen fertilizers [8].

The FAO states that permanent soil cover is a characteristic of conservation farming. Cover crops are useful for protecting the soil by providing an additional source of organic matter, recycling nutrients such as P_2O_5 and K_2O and mobilizing them in the soil profile, and utilizing nutrients that are easily leached, particularly N [3].

In a modern agricultural system, green manuring can be one of the best methods for sustaining soil health and crop yield [11].

In a long-term maize and sunflower cropping system, continuous use of nitrogenous fertilizers alone and an unfertilized control significantly decreased crop yields and soil fertility. Integrating the application of inorganic and organic fertilizers is critical for ensuring adequate nutrient delivery and sustaining crop productivity cropping method [10].

A wide variety of plant species have the potential to serve as green manures. Green manuring crops can be plant of grain legume

The most common cover crops in temperate regions of Europe are winter cover crops [6, 5, 4].

Green manuring crops can be plant in this region are legumes such as field pea or winter pea (*Pisum sativum* L. ssp. sativum var. arvense) [2]; cereals such as barley (Hordeum vulgare L.), triticale (*Triticosecale* Wittm.) and rye (*Secale cereale* L.) [2]; and brassicas such as white mustard (*Sinapis alba* L) and rapeseed (*Brassica napus* L.) [9].

The experiment was conducted to study the effect of green manuring in combination with nitrogen fertilizer on the yield of maize.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Research and Development Station (ARDS) Braila-Chiscani Experimental Center during the period from September 2021 to October 2022. Soil was a vermic chernozem with a medium humus content 2.4 - 3.1% in the upper horizons and only 1.6% in the transition horizon, 0.14-0.25 % total nitrogen content.

The experimental design employed was a fully randomized block design with four replications. The primary determinant of the plot was the green manure species, while the secondary factors were the mineral fertilization treatments carried out in the subplot. Each test plot had a surface area of 42 m^2, while the overall surface area of the research plot was 4,032 m^2 .

The experimental factors are as follows:

Factor A- Green manure crops

a_1– control – without green mure crop

a_2 - winter pea (*Pisum sativum* L. var. arvense.)

a_3- white mustard (*Sinapis alba* L.)

a_4- winter rye (*Secale cereale* L.)

a_5 - white mustard (*Sinapis alba* L.) + rapeseed (*Brassica napus* L.)

a_6- rapeseed (*Brassica napus* L.)

Factor B – Mineral fertilization

b_1– N_0 unfertilized

b_2- N_{60} (60 kg/ ha of N)

b_3- N_{90} (90 kg/ ha of N)

b_4- N_{120} (120 kg/ ha of N)

Green manure pure crops were sown after winter wheat according to the following norms: winter pea 180 kg/ha, white mustard 10 kg/ha, winter rye 170 kg/ha, white mustard 6 kg/ha + rapeseed 4 kg/ha, rapeseed 8 kg/ha. These were seeded in the first decade of September 2021. The chopping and incorporation of the green manure into the soil were carried out in the third decade of April 2022 using the rotary harrow at a depth of 10-15 cm. Mineral fertilization was achieved by administering a complex NPK 15:15:15

fertilizer at the same time as seedbed preparation, and fractional dosages of urea were applied during the V5 and V8 maize growth stages. This yielded a basic fertilization of 40 kg/ha P and 40 kg/ha K for all experimental variants. Overall levels of N applied by fertilization were 60 kg/ha for N60, 90 kg/ha for N90, and 120 kg/ha for N120.

Maize was sown in 04.05.2022 with F423 hibrid at a density of 65,000 plants ha and harvesting was performed in the second decade of October.

After the maize were harvested, samples were taken to measure the moisture in the lab using a hygrometer (Granomat Pfeuffer). Standardizing the moisture content of maize to 14%, which is the national standard for moisture content, production was computed (STAS).

The effect of green manure and N rate treatments on maize production was determined by measuring maize grain yield.

The study utilized Analysis of Variance (ANOVA) to evaluate variations in treatment outcomes. Additionally, a Fisher's protected Least Significant Difference (LSD) test was employed to ascertain the statistical significance of differences between the experimental factors and control, with p-values of 0.05, 0.01, and 0.001.

RESULTS AND DISCUSSIONS

On the whole, the agricultural year 2021–2022 was a deficit year in precipitation; the deficit recorded was 156 mm, and the thermal deviation was positive (+1.6 °C).

The year 2022 was characterized as an unfavorable year for maize crop with severe drought stress in May, June and July. For the growing period of maize the rainfall was significant less than multiannual average value, deficit reaching -112 mm.

The largest positive deviations of the average monthly temperatures as compared to the multiannual average are registered in the months: June (+ 1.8°C), July (+1.9°C) and August (+2.9°C). Under these conditions, it was necessary to apply a reduced irrigation water norm.

Table 1. Monthly and growing season temperature and precipitation at ARDS Braila 2021-2022

Months	Temperature (°C)		Precipitation (mm)	
	2021-2022	Multiannual average	2021-2022	Multiannual average
October	10.2	11.5	33.1	30
November	8.1	5.6	27.1	33
December	2.5	0.6	43.8	36
January	1.3	-2.1	6.5	28
February	4.1	-0.2	11.1	27
March	3.8	4.7	13.8	26
April	11.9	11.2	25.1	35
May	18	16.7	24.3	48
June	22.7	20.9	33.3	62
July	24.8	22.9	8.9	46
August	24.9	22	26.9	39
September	17.9	17.3	31.8	32
Average/ Total	**12.5**	**10.9**	**286**	**442**

Source: Meteorological Stations Braila.

Table 2. Influence of green manure on maize yield, 2022

Green manure crop	Yield		Differences		Significance
	kg/ha	%	±kg/ha	%	
a1- control	5,805	100	Mt		
a2- winter pea	6,929	119.4	1124	19.4	***
a3- white mustard	6,699	115.4	894	15.4	***
a4- winter rye	6,530	112.5	725	12.5	***
a5 white mustard + rapeseed	6,195	106.7	390	6.7	*
a6- rapeseed	6,588	113.5	784	13.5	***
LSD (5%)= 321.04 kg/ha; LSD (1%)=512.97 kg/ha; LSD (0.1%)=709 kg/ha					

Source: Own results.

Table 3. Influence of mineral fertilization on maize yield, 2022

Mineral fertilization	Yield		Differences		Significance
	kg/ha	%	±kg/ha	%	
b1-N0	6,458	100	Mt		
b2-N60	7,463	115.6	1,005	15.6	***
b3-N90	7,892	122.2	1,435	22.2	***
b3-N120	9,082	140.6	2,625	40.6	***
LSD (5%)= 198.65 kg/ha; LSD (1%)=264.6 kg/ha; LSD (0.1%)=344.41 kg/ha					

Source: Own results.

The influence of green manures on maize production is shown in Table 2. From the analysis of the presented data, the following results were obtained: Maize yield is influenced by green manure fertilization, so it increases from 5,805 kg/ha for the variant without green manure to 6,195 kg/ha for the variant with mustard and rapeseed, 6,530 kg/ha for the variant with rye, 6,588 kg/ha for the variant with rapeseed, and 6,699 kg/ha for the variant with mustard. The highest yield was achieved for the variant with peas, at 6,929 kg/ha.

Compared to the non-fertilized green manure control, all variants result in increased yield. Differences from the control are very significant for four of the variants, the highest yield increase was obtained in the pea variant with a yield increase of 1,124 kg/ha and a 19.4% yield increase. The variant with mustard and rapeseed recorded a significant difference, but the yield increase was smaller, only 6.7%. Upon examination of the yield outcomes resulting from the application of mineral fertilization (as presented in Table 3) in the absence of green manure fertilization, it appears that maize yields increased proportionally to the amount of mineral nitrogen applied, as follows: unfertilized 6,458 kg/ha, N60- 7,463 kg/ha, N90- 7,892 kg/ha, and N120- 9,082 kg/ha.

Table 4. Effect of integrated nutrient management on productivity of maize

Factor b- mineral fertilization	Factor a – green manure								
	a1- control			a2- winter pea			a3- white mustard		
	Yield (kg/ha)	Dif. (kg/ha)	Sign.	Yield (kg/ha)	Dif. (kg/ha)	Sign.	Yield (kg/ha)	Dif. (kg/ha)	Sign.
b1-N0	5,805	0		6,929	0		6,699	0	
b2-N60	6,297	492	*	7,883	954	***	7,907	1,208	***
b3-N90	6,710	906	***	8,359	1,430	***	8,416	1,717	***
b4-N120	7,284	1,479	***	9,491	2,562	***	10,292	3,593	***
Factor b- mineral fertilization	Factor a – green manure								
	a4- winter rye			a5- white mustard + rapeseed			a6- rapeseed		
	Yield (kg/ha)	Dif. (kg/ha)	Sign.	Yield (kg/ha)	Dif. (kg/ha)	Sign.	Yield (kg/ha)	Dif. (kg/ha)	Sign.
b1-N0	6,530	0		6,195	0		6,588	0	
b2-N60	8,009	1,479	***	7,664	1469	***	7,016	429	-
b3-N90	8,112	1,582	***	7,947	1752	***	7,809	1221	***
b4-N120	9,112	2,882	***	9,248	3053	***	8,767	2180	***
LSD (5%)= 486.58 kg/ha; LSD (1%)=648.13 kg/ha; LSD (0.1%)=843.64 kg/ha									

Source: Own results.

The analysis of the data presented in Table 4 shows that fertilization with mineral nitrogen on an unfertilized green manure background has less influence, with yield increases compared to the N0 variation ranging from 492 kg/ha to 1,479 kg/ha. The application of mineral nitrogen doses on a green manure with a mustard background resulted in a progressive increase in the yield obtained, the increases being the highest compared to the other variants, with the yield increases compared to the N0 variant ranging from 1,208 kg/ha to 3,593 kg/ha. From the analysis of the data in Table 4, it can be seen that the influence of nitrogen fertilization is very significant for all variants. Only the N60 variant on an unfertilized background showed a significant difference, and the N60 variant on a green manure background showed an insignificant difference.

CONCLUSIONS

The results of this study show the benefits of integrated fertilization with green manure and mineral fertilizer. Maize grain yield was found to be enhanced by using green manure crops.

The year 2022 was characterized as an unfavorable year for maize crop with severe drought stress in May, June and July.

Based on the analysis of production data when mineral fertilizer was used without green manure fertilization, it appears that maize yields increased proportionally to the amount of mineral nitrogen applied, as follows: unfertilized 6,458 kg/ha, N60 7,463 kg/ha, N90- 7,892 kg/ha, and N120- 9,082 kg/ha.

Compared with the no green manure crops treatment, the variant with white mustard and N120 obtained a high yield per hectare, respectively 10,292 kg/ha, which preceded the variant with winter pea and N120 with a production of 9,491 kg/ha.

Given an optimal growing environment for green manure, incorporation of the generated biomass will increase maize yield.

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