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Research on the Influence of Some Fertilization Variants on Maize Yield

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ABSTRACT

Green manures can improve soil structure through nutrient growth, but also crop production, playing an important role in sustainable agriculture. The objective of this study is to research the effect of different cover crops as green manure on maize yield. The experience was located at the Agricultural Research and Development Station Turda and included multiple variants of maize fertilization, which was sown on three agro-funds: classic and after the incorporation of crops used as green manures, namely lupine and phacelia. From the results obtained through this study, it can be seen that the highest maize yields (6,045 kg/ha) were obtained when the maize was sown after the incorporation of lupine, in the variant where ammonium nitrate was additionally applied.

1. Introduction

Due to the very high productivity and multiple uses of its products, maize is one of the most important culture in the world, with over a billion tons harvested on year (https://www.fao.org/faostat/en/#data/QCL/visualize). This cereal crop originating in Mexico was domesticated 9000 years ago and its cultivation had a significant impact on the development of human civilizations, becoming a staple food source for the entire world (Adekiya et al., 2020). However, the productivity of maize is largely dependent on effective nutrient management practices (Haribhushan et al., 2017). Integrated nutrient management, which combines the use of organic and inorganic fertilizers, has been shown to be a sustainable approach for enhancing maize yields while maintaining soil fertility (Ponmozhi et al., 2019). Soil is a fundamental resource for life, and maintaining soil health, reducing degradation and improving its structure is an adaptation to the current technologies used in agriculture (Vojnov și colab., 2022). Green manures are cover crops, which involve growing plants to cover the soil without harvesting and incorporated into the soil to maximize their various agricultural benefits (Blanco-Canqui, 2018). Introduction of these green manures in cropping systems is one of the solutions for soil conservation and improvement, can provide economic and environmental benefits and plays a very important role in adjusting cropping systems towards sustainable agriculture (Yang et al., 2016). In the

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context of maize culture, the influence of green manures on cover crop yields is of particular interest (Pu et al., 2023).

Among the benefits of green manures are: preventing erosion and soil degradation (Fageria, 2007); increase in organic matter content; soil moisture conservation; water quality correction; improving environmental biodiversity, by creating unpolluted spaces for pollinators and useful insects; a higher organic carbon content; protection of the soil surface by mitigating the negative impact of the works; increase and fixation of nitrogen content; providing nutrients for the next crop (Lehman et al., 2015); the decrease in temperature from the soil level due to the shadow effect and the microclimate created by the vegetation (Bogužas et al., 2015; Ruffo et al., 2004).

Cultivated over the years, as the soil accumulates their beneficial effects, cover crops can bring multiple benefits, and according to some authors, they can create the economic yield of cultivated crops even from the first year of cultivation (Chen and Weil, 2011; Meyer et al., 2022). The plants used as green manure must be not pretentious about the nutrients in the soil and give in a short time a large amount of green mass, rich in nutrients (Asghar and Kataoka, 2022). Some studies report that leguminous green manures have been shown to be more effective than other species in improving soil health and crop productivity (Bhattarai et al., 2012). Incorporation of green manures is recommended to be done a maximum of two weeks earlier than the sowing of the main plants, before they reach maturity (Pu et al., 2023). Otherwise they will develop a strong root system, the seeds will ripen and there is a risk of being disseminated throughout the lot,and as a result it could create a new problem, that is, combating them, being considered weeds in the main culture. Worldwide, but also in our country, the possibility of using cover crops as green manure or as a source of organic matter is reported in numerous studies (Liu et. al., 2020; Ferreira et al., 2020; Chețan et al., 2022). Based on all of the above, the present study investigates the effect of different green manures on the growth and yield of maize, the experimental variants including different types of fertilization.

2. Material and methods

In the spring of 2024, at Agricultural Research and Development Station (ARDS) Turda (Cluj county, Romania), a experience was organized in which cover crops used as green manures were used for the maize crop.

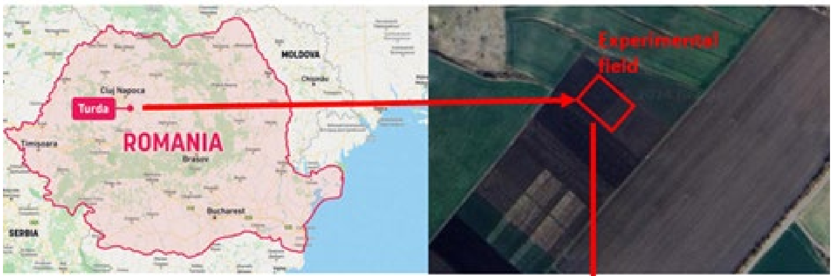
The research started from the idea to optimizing maize yield and quality through combined fertilization using agroecological methods to enhance nutrient cycling and soil health. By incorporating cover crops as green manures, farmers can improve soil fertility, reduce reliance on synthetic fertilizers, and enhance the overall sustainability of their farming systems (Price et al., 2019).

Two plant species were used for cover crops, namely: white lupine (*Lupinus albus*) and phacelia (*Phacelia* sp.). Incorporating white lupine as a green manure before maize sowing can significantly improve soil health, nutrient availability, and overall maize productivity (Zhang, 2019). White lupine is a legume, meaning it has a symbiotic relationship with nitrogen-fixing bacteria in its root nodules (Daryanto et al., 2018). These bacteria convert atmospheric nitrogen into a form usable by plants, enriching the soil with nitrogen. The extensive root system of white lupine improves soil structure, increasing water infiltration and aeration, and also produces a substantial amount of biomass, which contributes to soil organic matter when incorporated as green manure (Zhang, 2019). White lupine is adaptable to a range of soil types and climates, making it a versatile green manure option (Tripolskaja et al., 2023).

Phacelia is a popular choice for a green manure and compared with lupine, offers a different set of benefits. Phacelia grows quickly, producing a large amount of biomass in a short period and this makes it an effective green manure for suppressing weeds and adding organic matter to the soil (Qamar et al., 2006). This plant is excellent at capturing nutrients from the soil, preventing them from leaching, and its roots improve soil structure by increasing porosity and water infiltration (Chapagain et al., 2020). Unlike white lupine, phacelia is not a legume and does not fix nitrogen, however, it excels at holding onto nitrogen in the soil, preventing it from being lost (Chapagain et al., 2020). Phacelia is a valuable pollinator plant, attracting bees and other beneficial insects to the field (Qamar et al., 2006).

The biological material used was hybrid maize Turda 344, created at ARDS Turda. It is a trilinear hybrid, semi-early, with good resistance to low temperatures in the first part of the vegetation period, good resistance to plant fall and stem breakage. This hybrid is part of the maturity group FAO 380 (Haș et al., 2014).

The experience has been placedon an Chernozemsoil (Florea, 2012), where Turda 344 maize hybrid was grown in three agro-funds, namely: classic with all chemical and organic fertilization variants, after lupine and phacelia used as green manures with all organo-mineral fertilization variants. The sown area of the variants was 21 m^2 (4.2 m wide x 5 long) in three repetitions, and the total area of the experience was 945 m^2, the preceding plant being all maize.



Agrofund Phacelia	R3	4	2	5	1	3
	R2	3	5	1	2	4
	R1	1	2	3	4	5
Agrofund Lupine	R3	4	2	5	1	3
	R2	3	5	1	2	4
	R1	1	2	3	4	5
Agrofund Classic	R3	4	2	5	1	3
	R2	3	5	1	2	4
	R1	1	2	3	4	5

Figure 1. Location of the trail and experimental design showing the main analyzed factors: green manures and the fertilization variants

1. Basic fertilization (N:P:K - 20:20:0); 2. Additional fertilization with mineral fertilizers (NH_4NO_3); 3. Additional fertilization with the product Micro-bio nutrient; 4. Additional fertilization with the Maxi Grow biostimulator; 5. Additional fertilization with the root biostimulator Rootip basic

The additional fertilization with mineral fertilizers involved the application of ammonium nitrate at a rate of 100 kg/ha, while the basic fertilization was done with complex fertilizers of the N:P:K (20:20:0) + sulfur type in a dose of 300 kg/ha. The basic fertilization was present in all variants.

Micro-bio nutrient organic fertilizer is a microbiologically active product, the composition of which is derived from the composting of manure from bio-accredited zootechnical farms. This product was foliarly applied in two growth stages: an application during the two-leaf stage and another application in the eight-leaf stage, both at a rate of 2 l/ha (https://www.fabricadecompost.ro/micro-bio-nutrient-cereale).

Biostimulator Maxi Grow is a foliar fertilizer that enhances metabolic activity by supplying bio-molecules that the plant can no longer synthesize normally under difficult climatic conditions. The foliar application was applied when the corn was at the eight-leaf stage, with a dose of 0.5 l/ha. (https://seminte-agro.ro/produse/biostimulator-maxi-grow).

Rootip basic, a root biostimulator, was created to stimulate the appearance and development of new absorbent roots, thereby ensuring the absorption of nutrients from the soil. It was foliarly applied at a dose of 3 l/ha when the corn was in the eight-leaf stage (https://www.naturevo.ro/produse/rootip-basic-biostimulator).

Sowing was carried out with the help of the MT-6 machine at a thickness of 65.000 plants ha⁻1, and the basic fertilization was applied concurrently with sowing. The seeds were treated with Fludioxonil and Metalaxil-M at a rate of 1 liter per tonne of seed. To combat weeds, two treatments were applied, namely: pre-emergence, before crop emergence with Glyphosate at a dose of 1 l/ha, Merlin Flexx 0.4 l/ha (isoxaflutol + cyprosulfamide) and Frontier Forte 0.8 l/ha ha (dimethenamid-P). After the emergence of the crop, in the phenophase of six leaves, another herbicide was applied using Amino 1 l/ha (acid 2,4 D) and Nicogan 40 OD 0.8 l/ha (nicosulfuron). The culture used as green fertilizers were sown at the beginning of March (03.05.2024), with the help of the Nina Maschio Gaspardo 250 machine, and their incorporation (figure 1) was carried out with the tiller three days before the sowing of maize.

The harvest of the maize experiment was gathered manually, by meeting the methodological rules of the experimental technique.

Figure 2. Using cover crops as green manures before maize sowing (Lupine and Phacelia)

Source: (original)

The data were processed by using ANOVA by Anova PoliFact Soft (Cluj-Napoca, Romania). A Fisher's protected least significant difference (LSD) test was used to determine the significance of the differences among the variance results and control (for p-values 0.05, 0.01, and 0.001) for each experimental factor.

3. Results and discussions

Based on long-term data (1957–2022), the mean annual air temperature is 9,2 ^{0}C and the total annual precipitation sum is 532,5 mm. Monthly precipitation and temperature data were collected from the Turda Meteorological Station, wich is located at the ARDS Turda perimeter (located in the Transylvanian Plain, Romania), with longitude coordinates 23°47′; latitude 46°35′; altitude 427 m.

In Romania, maize is the most widespread crop, and its cultivation in the Transylvanian Plateau is totally dependent on the amount of water from precipitation and groundwater supply, therefore monitoring climatic parameters is extremely important (Șimon et al., 2023). Although the maize is a culture that is quite tolerant to drought and high temperatures,regarding the climatic conditions, the year 2024 was not a favorable year for this culture, in most regions of our country. According to climate data recorded at ARDS Turda, this year began with a warm month and continued similar until September, with the exception of May, which was the only month characterized as normal. Compared to the 65-year average, the monthly averages showed substantial deviations, with positive increases observed throughout the period from January to September. During the maize vegetation period, the highest deviations were recorded in July and August, during this period there were also days with temperatures above 38^{o}C, negatively influencing both vegetative and generative processes. In a study conducted by Șimon et al. (2023), the results obtained show that increase of temperature during the vegetation period, negatively influenced the maize yield, and an inverse relationship was determined between temperature and yield.

Table 1. Average temperatures recorded in January – September, in the year 2024, at Turda

Month	Monthly average	Average 65 years	Deviation (+-)	Characterization
January	0,2	-3,3	3,5	warm
February	7	-0,6	7,6	very warm
March	8,8	4,4	4,4	warm
April	13,3	10	3,3	warm
May	15,8	15	0,8	normaly
June	21,7	18	3,7	warm
July	24	19,8	4,2	warm
August	23,4	19,5	3,9	warm
September	17,9	15,2	2,7	warm

Source of climate data: Turda Meteorological Station

Waha et al. in 2013, found that a decrease in rainfall is very important for maize yield, even exceeding the effect of temperature on maize yield, even exceeding the effect of temperature on maize yield. In more studies it is reported that insufficient rainfall also affects the final yield of corn to varying degrees (Șimon et al., 2023; Guna et al., 2019) which is consistent with the results of our study.

In addition to the high temperatures in 2024, drought also intervened, another limiting factor in the formation of maize yield. As can be seen in table 2, the maize vegetation period was characterized by dry or excessively dry months the deviations from the multiannual average being quite high, especially in the summer months, which negatively marked the quantity and quality of culture. The highest deviation was registered in June, with a deficit of -48.4 mm. A large amount of rainfall was recorded at the end of September, when 26.4 mm fell in a single day, but very late for maize production.

Table 2. The amount of precipitation in January – September recorded at Turda in the year 2024

Month	Monthly average	Average 65 years	Deviation (+-)	Characterization
January	4,8	21,7	-16,9	excessively dry
February	9,2	19,2	-10	excessively dry
March	37,7	24,3	13,4	excessively rainy
April	38,8	45,6	-6,8	a bit dry
May	60,7	69,4	-8,7	a bit dry
June	36,2	84,6	-48,4	excessively dry
July	49	78	-29	very dry
August	37	56,1	-19,1	excessively dry
September	64	42,4	21,6	excessively rainy

Source of climate data: Turda Meteorological Station

Being a plant that it has a great need for precipitation during the critical phenophases of emergence, flowering, silking, and grain filling, the lack of adequate water during these developmental stages can result in considerable decreases in yield (Alqudah et. al., 2011). At the same time, fertilization has a significant role in determining the yield parameters of this culture, being a subject widely discussed (Ibrahim et al., 2021; Barșon et al., 2021;). But in addition to mineral or organic fertilization, in many studies it is reported that green manures contribute to increasing the yield of the maize culture (Mahama et al., 2016). In 2011 Chen et al. registered an increased maize yield from 1.60 to 2.43 tonnes per hectare, after incorporation of cover crops used as green manures. Due to the drought and high temperatures registered in 2024, maize yield was reduced in most regions from Romania, including the Transylvanian Plateau, as can be seen in table 3, quite reduced yield were recorded in all tested variants. Incorporating plants used as green manure into the soil before sowing led to increased crop production. Sowing after the incorporation of lupine as green manure led to higher production values. In a study by Liang et al. in 2022, it was observed that the application of green legume fertilizers significantly increased the yield of cereal crops, compared to no application. Regarding fertilization, the variant to which ammonium nitrate was additionally applied, the highest yield was obtained in all three agrofunds. Adequate nitrogen supply from ammonium nitrate promotes vigorous vegetative growth, leading to increased corn yields (Zhou et al., 2019). Several studies have highlighted the positive impact of nitrogen on maize yield, for example (Araújo et al., 2004) shows a 28% yield increase with nitrogen fertilization. However, excessive use of ammonium nitrate can lead to nitrogen leaching into groundwater and surface water, causing environmental pollution (Gramma et al., 2020), that's why green manures can be an alternative to chemical fertilizers.

Sown after lupine, maize seems to have reacted best in all five variants, the highest yield being recorded in the variant to which additional ammonium nitrate was applied, with an increase of almost 500 kg compared to the classic one, recording significantly positive differences compared to the control.

Table 3. The influence of the agrofund x fertilization interaction on yield

No. Crt.	Agrofund	Variant	Yeld (kg/ha)	%	Diferences	Significance
1.	Classic	Basic fertilization (control)	4969	100.0	0.00	Mt.
2.		NH4NO3	5603	112.8	634	-
3.		Micro-bio nutrient	5304	106.7	335	-
4.		Maxi Grow	5423	109.1	453	-
5.		Rootip basic	5348	107.6	379	-
1.	Lupine	Basic fertilization (control)	5350	100.0	0.00	Mt.
2.		NH4NO3	6054	113.2	704	*
3.		Micro-bio nutrient	5473	102.3	123	-
4.		Maxi Grow	5680	106.2	330	-
5.		Rootip basic	5465	102.2	115	-
1.	Phacelia	Basic fertilization (control)	5028	100.0	0.00	Mt.
2.		NH4NO3	5771	114.8	743	*
3.		Micro-bio nutrient	5348	106.4	320	-
4.		Maxi Grow	5455	108.5	427	-
5.		Rootip basic	5362	106.6	333	-
LSD (p 5%)					642.9	
LSD (p 1%)					873.8	
LSD (p 0.1%)					1120.7	

The processes of germination and emergence of plants are strongly influenced by the size of the grains, as this characteristic depends on the size of the embryo and the quantity of reserve substances required to complete these stages (Kermode, 2005; Cantoro et al., 2013). Larger grains tend to have more robust embryos and greater reserves of nutrients, while smaller grains may struggle to access the resources necessary to complete these early developmental stages (Limón-Ortega et al., 2016; Fiaz et al., 2021). Also, the TKW is closely related to production, but also to fertilization. From table 4 it can be seen that in all three agrofunds the highest values of TKW were obtained in the variants to which ammonium nitrate was additionally applied. The incorporation of lupine into the agrofund appears to play a role in the formation of the TKW, with the highest value being obtained in this case (268,3 g). Significantly positive differences were recorded for two fertilization options (ammonium nitrate and Maxi Grow) compared to the control variant.

Table 4. The influence of the agrofund x fertilization interaction on the TKW

No. crt.	Agrofund	Variant	TKW (g)	%	Diferences	Significance
1.	Classic	Basic fertilization (control)	229.33	100.0	0.00	Mt.
2.		NH4NO3	266.00	116.0	36.67	**
3.		Micro-bio nutrient	231.33	100.9	2.00	-
4.		Maxi Grow	265.67	115.8	36.33	**
5.		Rootip basic	257.67	112.4	28.33	*

No. crt.	Agrofund	Variant	TKW (g)	%	Diferences	Significance
1.	Lupine	Basic fertilization (control)	239.67	100.0	0.00	Mt.
2.		NH4NO3	268.33	112.0	28.67	*
3.		Micro-bio nutrient	254.33	106.1	14.67	-
4.		Maxi Grow	267.00	111.4	27.33	*
5.		Rootip basic	257.00	107.2	17.33	-
1.	Phacelia	Basic fertilization (control)	243.67	100.0	0.00	Mt.
2.		NH4NO3	267.00	109.6	23.33	-
3.		Micro-bio nutrient	248.33	101.9	4.67	-
4.		Maxi Grow	264.67	108.6	21.00	-
5.		Rootip basic	264.00	108.3	20.33	-
LSD (p 5%)					23.75	
LSD (p 1%)					32.28	
LSD (p 0.1%)					43.23	

The quality of maize is largely determined by its starch and protein contents, which can be influenced by various environmental factors, such as climate and local conditions (Shi et al., 2017). As can be seen from table 5, the protein content varies between the limits of 6.41 and 7.18, statistically differences were recorded only in the variant from the classic system with mineral fertilization, namely where ammonium nitrate was applied to phase fertilization.

Table 5. The influence of the agrofund x fertilization interaction on protein content

No. Crt.	Agrofund	Variant	Protein (%)	%	Diferences	Significance
1.	Classic	Basic fertilization (control)	6.41	100.0	0.00	Mt.
2.		NH4NO3	7.11	111.0	0.70	**
3.		Micro-bio nutrient	6.59	102.9	0.19	-
4.		Maxi Grow	6.85	106.9	0.44	-
5.		Rootip basic	6.56	102.3	0.15	-
1.	Lupine	Basic fertilization (control)	6.79	100.0	0.00	Mt.
2.		NH4NO3	7.07	104.1	0.28	-
3.		Micro-bio nutrient	6.94	102.2	0.15	-
4.		Maxi Grow	7.01	103.2	0.22	-
5.		Rootip basic	6.67	98.1	-0.13	-
1.	Phacelia	Basic fertilization (control)	7.18	100.0	0.00	Mt.
2.		NH4NO3	6.91	96.2	-0.27	-
3.		Micro-bio nutrient	6.80	94.7	-0.38	-
4.		Maxi Grow	7.12	99.1	-0.07	-
5.		Rootip basic	7.05	98.2	-0.13	-
LSD (p 5%)					0.48	
LSD (p 1%)					0.65	
LSD (p 0.1%)					0.87	

4. Conclusions

The results of this study indicate that green manures contributed to maize yield, although no significant differences were observed between the three agricultural agro-funds.

Regarding the mass of 1000 grains, in both control variants sown after lupine and phacelia, the values of this parameter were slightly higher, compared to the classic system, which shows that green manures have a positive role on TKW. Understanding the factors that influence the yield and protein content of maize is essential for developing strategies to optimize crop quality and address the growing gap between food consumption and production, particularly in water-scarce environments.

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