PRELIMINARY RESULTS REGARDING THE EFFECTS OF GREEN MANURES ON WHEAT CULTIVATION ON THE ACIDIC SOILS OF THE NORTH-WEST REGION OF ROMANIA

Peter-Balázs ÁCS[1,2,*], Ioan PĂCURAR[1], Beniamin-Emanuel ANDRAȘ[1,2], Patrick Andrei URSAN[1,2], Susana MONDICI[2]

[1]University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca
[2]Livada Agricultural Research and Development Station
[*]Correspondig author: acsbalazs24@gmai.com; peter-balazs.acs@student.usamvcluj.ro

Abstract. *This study addressed the burgeoning interest in ecological agriculture, emphasizing sustainable and regenerative practices. Among these, the utilization of green manures emerged as pivotal for enhancing soil health and augmenting the yield of nutritionally dense crops. Five plant species (triticale, peas, soybeans, sunflower, and rapeseed) were selected for incorporation, sown during the summer, and subsequently integrated into the soil while still in their vegetative phase, preceding the optimal sowing window for wheat. The experiment encompassed three repetitions for the principal crop, of wheat implemented through split-plot design. Each repetition comprised both a fertilized and an unfertilized plot, further sub-divided, with certain segments receiving fungicidal treatment and others left untreated. The experimental setup was situated on an albic luvisol, exhibiting humus content ranging from 1% to 1.8% in the plow layer, coupled with an acidic pH range of 4.2 to 5.3. The trial site was located within the experimental fields of the Plant Protection Laboratory at theLi vada Agricultural Research and Development Station, Satu Mare County.The primary aim of this experiment was to evaluate the influence of green manures, including their synergistic interplay with chemical fertilizers (calcium ammonium nitrate 27% N), on wheat. Evaluative parameters encompassed yield metrics, weed infestation levels, disease and pest resistance, along with the quality attributes of the principal crops. Ultimately, the study sought to furnish a encompassing comprehension of the advantages conferred by this regenerative agricultural practice, within the contemporary framework of ecological and agronomic imperatives. In conclusion, the inaugural year of experimenting with green manures did not yield an immediate augmentation in crop yield. However, it became evident that additional fertilization was required to fully harness the benefits of green manures. Encouragingly, the data spotlighted a propitious finding green manures bolstered the disease resistance of wheat, implying enduring advantages for crop health. Furthermore, the adoption of rapeseed and peas as green manure crops, demonstrated a noteworthy reduction in weeding, affording an economical and pragmatic edge for sustainable agricultural practices. Additionally, when amalgamated with chemical fertilizers, the interaction with green manures evinced an augmented production capacity, underscoring the potential for a synergistic strategy in maximizing crop output. These revelations highlight the significance of a holistic and integrated approach to agricultural methodologies, underscoring the value of amalgamating green manures with judicious fertilization strategies. As we persist in our exploration and refinement of these techniques, the potential for enhancing both productivity and sustainability in our agricultural systems remains considerable, ultimately contributing to a more resilient and efficient food production process.*

Keywords: *green manures, acidic soils, wheat, soil fertility, fertilizers*

INTRODUCTION

Green manures are composed of specific plants that are cultivated with the purpose of incorporating them into the soil during basic agricultural operations. The plants used as green manure should produce a rich vegetative mass in as short a time as possible and should not be demanding in terms of soil. The plants used for this purpose are mostly legumes, but other plants can also be used as well. (Dumitru et al., 2003), (Davidescu et al., 1981). This technique involves growing plants, such as legumes or grasses, and subsequently incorporating them into the soil before they reach maturity. The decomposition of these plants enriches the soil with organic matter, nutrients, and beneficial microorganisms. (Drinkwater et. al. 2007).

Le Blanc (2023) mentions that the incorporation of plant biomass into soil as green manures can reduce soil borne diseases and improve crop and soil health in agricultural ecosystems.

Soil degradation is a major threat to crop yield all over the world. Land degradation includes loss of soil fertility and biodiversity. It has been estimated that about one-third of farmland have deteriorated in the last four decades, and the fertile layer of topsoil will become unproductive in the coming 60 years if deterioration continues at the same rate (Naz et al., 2023).

Naz et al. (2023) also states that green manuring crops are comprised of above- and below-ground biomass. They have the ability to capture solar energy and convert it into carbon flux, which is useful for releasing macro and micronutrients to the soil biota. Green manuring with legumes can fix atmospheric N and provide it to the plants in an available form and also add organic matter to maintain soil fertility. Research has shown that the use of green manure can have several positive effects on agricultural systems. Firstly, it enhances soil structure, promoting better water infiltration and retention, which ultimately leads to improved moisture management. Additionally, green manure contributes to increased nutrient availability, particularly nitrogen, phosphorus, and potassium, reducing the reliance on synthetic fertilizers. This practice also aids in weed suppression, as the cover crops compete with undesirable plants for resources and space (Mäder et al., 2002).

Furthermore, green manure supports biodiversity by providing habitat and food sources for beneficial insects and soil organisms. It also reduces soil erosion by stabilizing the soil surface with a protective cover of vegetation. Moreover, green manure has been found to mitigate greenhouse gas emissions, sequestering carbon in the soil and reducing the need for energy-intensive farming practices (Tonitto et al., 2006).

MATERIAL AND METHODS

Soil characteristics

The experience is located inLivada, Satu Mare county on an albic luvisol. Albic Luvisol, classified under the World Reference Base for Soil Resources (WRB), is a type of soil found in various regions around the world. It is characterized by a distinctive horizon known as the albic horizon, which is typically light in color due to leaching of minerals and organic matter. This horizon often exhibits a higher clay content compared to underlying horizons, contributing to its unique properties. (IUSS Working group, 2015), (Fao, 2006). In the upper horizon, there is a low humus content, with a moderate supply of mobile phosphorus, low mobile potassium, and a strongly acidic reaction, with the pH in water of around 5.2. (Boeriu et al., 1987). Soil pH is the most important indicator measured for estimating soil health especially in mine soils, since it has a great influence on key soil processes. (Buta et al., 2019) The pronounced acidification, low supply of humus and potassium, and the defective air-water regime impose serious restrictions on crop cultivation (Kurtinecz et al., 2022). Additionally, Albic Luvisols play a role in carbon sequestration, helping to mitigate climate change (Arrouays et al., 2002).

The crust formation index has values between 1.8-2.2 (Canarache, 1987), often leading to the compromise of crops with epigeic germination, an aspect that can only be improved through the addition of organic matter, which facilitates soil structure. Additionally, the addition of organic matter improves water permeability, soil warming, and intensifies microbiological activity, which are deficient aspects in these types of soils, where surface puddles or erosions are frequent.

Table 1. The main physico-chemical parameters of Albic Luvisol at Livada ARDS

Horizon	UM	Ap	Ao		AB	Bt1w	Bt2w
Horizon depth	cm	0-18	18-40		40-55	55-70	70-110
Sample depth	cm	0-15	20-30	30-40	40-55	55-70	80-95
Humus(Cx1,72)	%	1,82	1,44	0,90	0,90	0,84	3,24
N total	%	0,168	0,102	0,072	0,068	0,064	-
C : N	-	8,21	9,15	10,14	10,34	10,57	-
pH (H_2O)	-	5,19	6,24	6,65	6,53	5,62	5,28
SB	me/100g soil	5,20	6,26	6,53	8,85	10,23	11,02
Ca^{2+}sch	me/100g soil	4,22	5,46	5,41	6,70	7,07	7,25
Mg^{2+}sch	me/100g soil	0,77	0,63	0,96	1,91	2,84	3,49
K^{+}sch	me/100g soil	0,18	0,12	0,12	0,20	0,25	0,23
Na^{+}sch	me/100g soil	0,03	0,05	0,04	0,04	0,06	0,06
V%	% din T	53,5	73,2	77,8	79,8	71,1	69,5
P- AL	ppm	13,6	24,0	10,2	-	-	-
K-AL	ppm	100	87	87	-	-	-
Clay(< 0,002 mm)	% g/g	20,9	21,1	23,1	27,0	32,4	33,1
Apparent density	g/cm³	1,35	1,54	1,49	1,48	-	1,48
Hydraulic conductivity	mm/h	1,3-4,0	5,87	3,11	0,35	-	1,04

Climate data

In recent times, climate changes have become increasingly evident, reflected by the lack of precipitation, the onset of excessive heat, and the rise in average annual temperature. Positive or negative temperature variations are reflected in the evolution of the vegetation state of agricultural crops and, consequently, in their yield capacity. Over the past 10 years, the lowest average annual temperature was recorded in 2021. This was 0.1 degrees Celsius higher than the multi-year average temperature. In terms of annual precipitation, which is the main source of water for agricultural crops in the north-western region of Romania, it can be observed over the course of 60 years of climate data recording that the precipitation regime varies from year to year and is unevenly distributed throughout the years (Andraș et al., 2022).

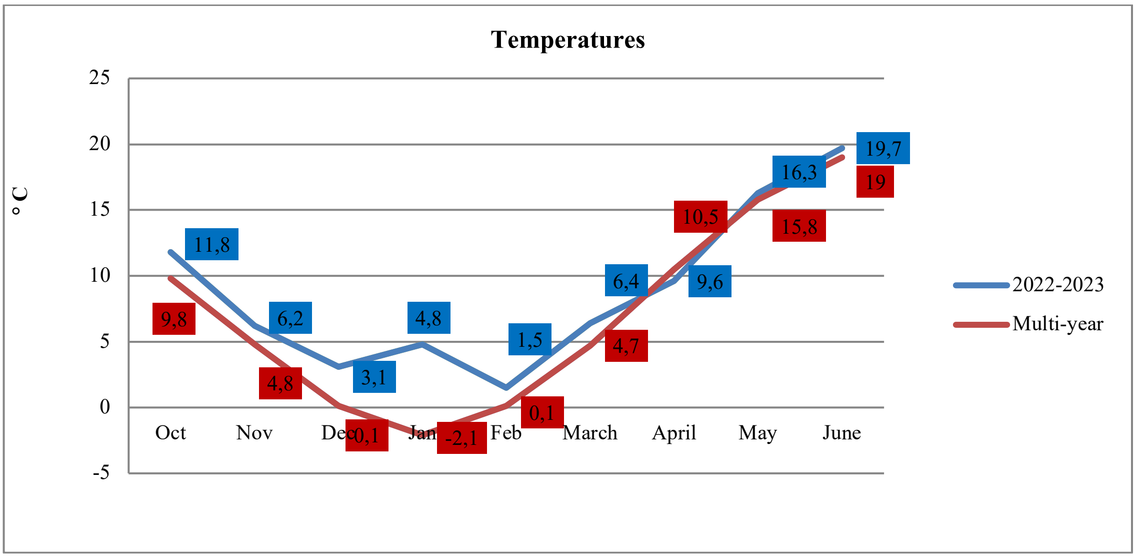

Figure 1. Comparison of Wheat Vegetation Period Temperature Ranges with Multi-Year Trends

The region experiences an average annual temperature range of 8˚C to 10˚C. The accumulation of heat units above the threshold of 10˚C in the plain area varies between 1200 and 1450˚C. Over the past six decades, the Livada station has recorded an average temperature of 9.9˚C.

Analyzing the multi-year average monthly temperatures, it is evident that January constitutes the coldest month, whereas July stands out as the warmest month.

The thermal characteristics of the cold period are delineated by the computation of cold and frost units spanning from November to March. Notably, the highest frequency is observed in years with cold unit values ranging between -100˚C and -200˚C, indicative of generally milder winters. The onset of the first frost is most likely to occur towards the end of October and the early half of November, while the concluding frost of the season typically takes place in March. This thermal regime information provides valuable insights into the climatic conditions governing the agricultural landscape in the region.

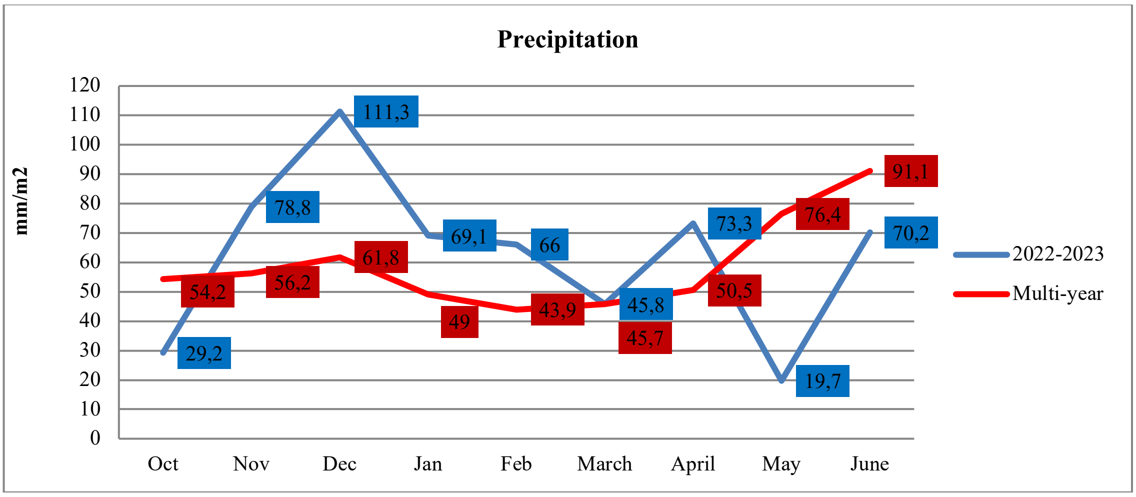

Figure 2. Comparison of Wheat Vegetation Period Precipitation with Multi-Year Averages

As discernible from the graph, the distribution of precipitation throughout the wheat growing season exhibited marked irregularities in comparison to the multi-year average. Particularly notable were the significant deviations observed in December, wherein precipitation levels surpassed 100 millimeters per square meter, and in May, when the recorded precipitation dwindled to less than 20 liters. These disparities underscore the notable departures from typical seasonal precipitation patterns, which may have notable implications for crop development and agricultural management strategies.

Field layout

The primary objective of this experiment is to assess the influence of green manures, both individually and in combination with chemical fertilizers, on the cultivation of wheat. The comprehensive evaluation encompasses key parameters such as yield, weed infestation levels, resistance to diseases and pests, as well as the overall quality of the main crop.

The experimental design incorporates three repetiotions and employs a split-plot configuration, featuring three distinct experimental factors. These factors are denoted as Factor A, pertaining to the type of green manure utilized; Factor B, concerning the application of chemical fertilizers; and Factor C, focusing on fungicide treatment. (Figure 3.)

The five selected plant species, namely triticale, peas, soybeans, sunflower, and rapeseed, were sown during the summer season and subsequently integrated into the soil at the green growth stage, strategically timed prior to the optimal period for sowing wheat.

In terms of chemical fertilization, Calcium ammonium nitrate characterized by a nitrogen content of 27% was employed, administered at a rate of 450 kilograms per hectare (kg/ha) in two phases: 225 kg in the autumn season and an additional 225 kg in the spring.

For fungicide treatment, a commercially available product comprising active substances including protioconazole (53 g/L), spiroxamine (224 g/L), and tebuconazole (148 g/L) was utilized at a dosage of 1 liter per hectare (L/ha). Two distinct treatment applications were administered.

This comprehensive experimental setup aims to elucidate the intricate interplay between green and chemical fertilizers, in conjunction with fungicide treatment, on the performance and outcomes of wheat cultivation.

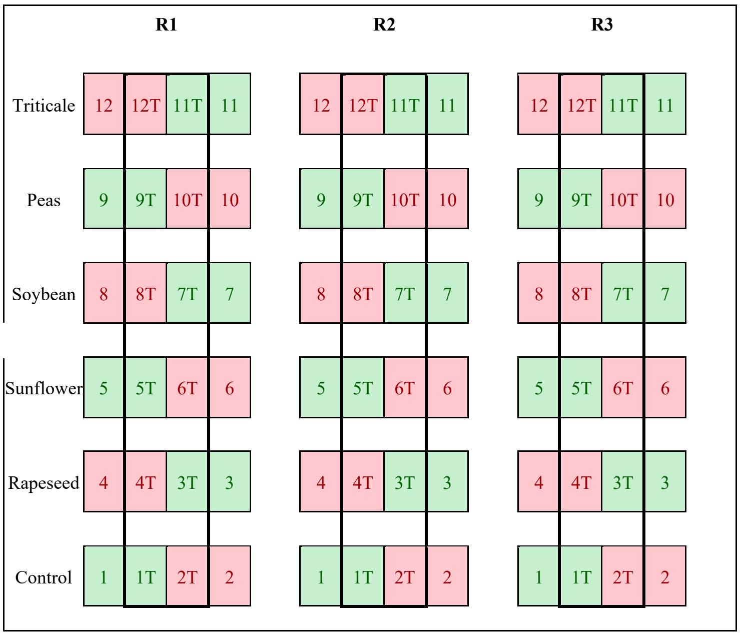

Figure 3. The field layout of the experiment

RESULTS AND DISCUSSIONS

Weeding

In the context of weed infestation, the study unveiled significant occurrences that merit attention. Firstly, a noteworthy observation was made in relation to the unfertilized green manure triticale plot, where the weed density exceeded 40 plants per square meter. This marked proliferation of weeds in the triticale plot underscored the potential challenges associated with foregoing fertilization practices. Secondly, a comparable phenomenon was observed in the fertilized soybean green manure plot, where the weed density reached nearly 35 plants per square meter. This observation serves as a pertinent reminder of the complex interplay between fertilization strategies and weed proliferation, warranting further investigation into optimal management practices to mitigate such occurrences. These instances highlight the intricate dynamics at play within agroecosystems, emphasizing the need for meticulous monitoring and strategic intervention to safeguard crop yield and quality (Figure 4).

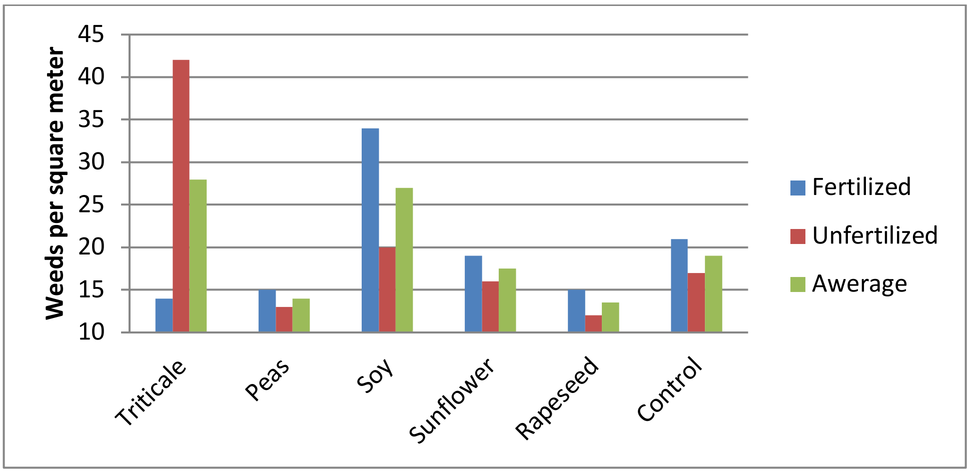

Figure 4. Level of weed infestation

Noteworthy among the prevalent weed species are Stellaria media, Cirsium arvense, and Viola arvenis, which stand out as dominant contributors to the observed weed infestation levels (Figure 5).

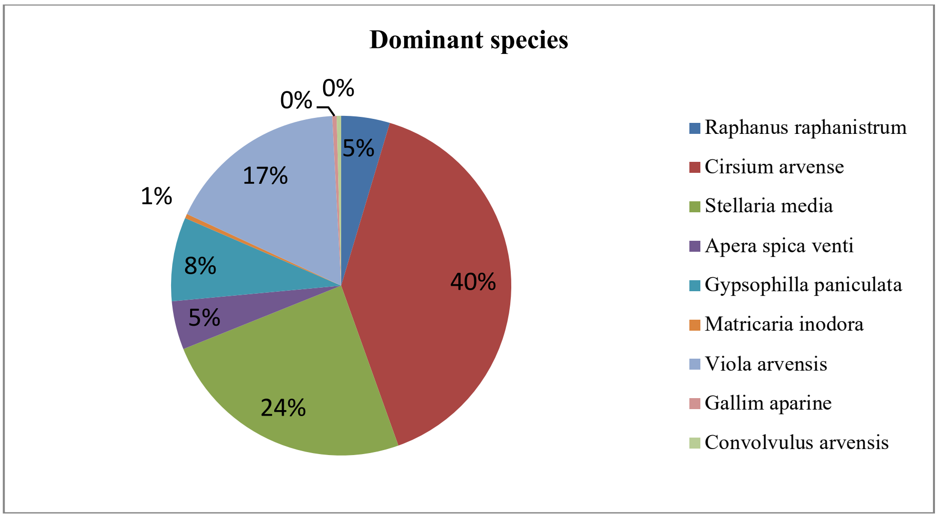

Figure 5. Dominant species of weeds

Leaf dryness

In the assessment of leaf drying percentage, a comprehensive evaluation encompassing the pathogen complex and prevalent diseases during the cultivation period in the experimental area was conducted. Notably, the occurrence of Septoria, yellow rust, and powdery mildew was observed. It is evident that chemical fertilization yielded no discernible impact on the leaf drying percentage. Conversely, with regard to phytosanitary treatment, a substantial disparity emerges. Specifically, treated variants exhibit a notable deviation of 41%, while untreated variants demonstrate a pronounced difference of 71.3% in leaf drying percentage. These findings underscore the marked influence of phytosanitary treatment in mitigating leaf drying associated with prevalent pathogens and diseases (Table 2.)

Table 2. Dryness leves on each experimental factor

Variant	Dryness %	Dryness %		Dryness %	
		Fertilized	Unfertilized	Treated	Untreated
Triticale	69.7	73.1	66.3	54.0	85.4
Peas	52.2	55.7	48.7	34.7	69.7
Soy	58.5	57.8	59.2	45.1	71.9
Sunflower	54.4	55.6	53.0	42.2	66.5
Rapeseed	48.2	47.8	48.5	43.3	53.0
Control	53.8	48.7	58.9	26.6	81.1
Average	**56.1**	**56.5**	**55.8**	**41.0**	**71.3**

The depicted graph below (Figure 6.) vividly illustrates a substantial disparity in green biomass production across various plant species. Notably, peas and sunflower stand out as the most prolific biomass producers, yielding quantities surpassing 22 tons per hectare. In stark contrast, soybeans exhibit a considerably lower biomass output, failing to exceed 1.5 tons per hectare. Triticale, with just over 4 tons per hectare, occupies an intermediate position, while rapeseed achieves a biomass yield of nearly 15 tons per hectare, positioning it in between the extremes represented by peas and sunflower on one end, and soybeans and triticale on the other.

This visual representation underscores the significant variation in biomass productivity among these diverse plant species.

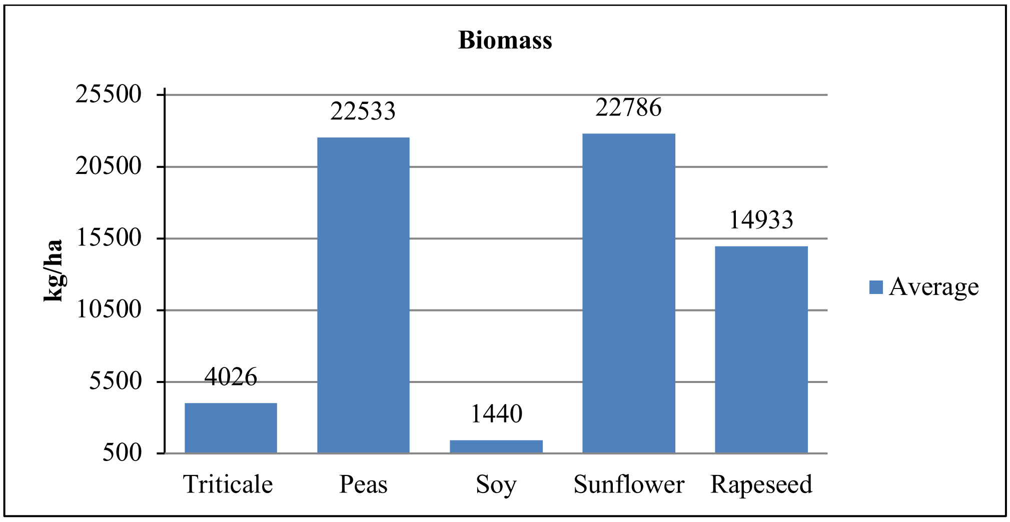

Figure 6. Biomass incorporated by plant species

Yield

In the context of the 2023 wheat crop yield analysis, in comparison to the control group achieving a yield of 5251 kilograms per hectare (kg/ha), noteworthy observations emerge regarding the influence of different green manure treatments. Notably, there is a substantial adverse impact on yield when utilizing green manures derived from triticale, sunflower, and rapeseed. Specifically, the influence is notably pronounced in the case of soybean crops, exhibiting a distinct and substantial negative effect. Conversely, the influence on yield from peas is comparatively negligible, with the wheat yield attaining 5140 kg/ha, presenting a marginal variance of merely 111 kg/ha in comparison to the control group (Table 3).

Table 3. The influence of green manure factor on yield

Number	Variant	Average (kg/ha)	Difference (kg/ha)	Significance
1	Triticale	4119	-1132	OOO
2	Peas	5140	-111	-
3	Soy	4858	-392	OO
4	Sunflower	4475	-776	OOO
5	Rapeseed	4551	-699	OOO
6	Control	5251	-	-
		CL (p 5%)	260	
		CL (p 1%)	370	
		CL (p 0.1%)	535	

In contrast, the application of chemical fertilizers manifests a notably positive effect on yield, resulting in a significant increase of 1264 kg/ha when compared to the average yield encompassing both fertilized and unfertilized conditions. These findings are statistically robust, providing a confident indication of the beneficial impact of chemical fertilization on wheat crop yield (Table 4).

Table 4. The influence of chemical fertilization factor on the yield

Number	Variant	Average (kg/ha)	Difference (kg/ha)	Significance
1	Fertilized	5996	1264	XXX
2	Unfertilized	3468	-1264	OOO
3	Average	4732	-	
	CL (p 5%)		159	
	CL (p 1%)		224	
	CL (p 0.1%)		316	

The impact of phytosanitary treatment on wheat crop yield demonstrates a marginal increase, with a mere 9 kilograms per hectare (kg/ha) discrepancy observed. This observation underscores the relatively modest effect of the applied phytosanitary measures on overall crop productivity in this context (Table 5).

Table 5. The influence of fungicide treatment factor on the yield

Number	Variant	Average (kg/ha)	Difference (kg/ha)	Significance
1	Treated	4741	9	-
2	Untreated	4723	-9	-
3	Average	4732	-	
	CL (p 5%)		171	
	CL (p 1%)		232	
	CL (p 0.1%)		311	

The synergistic application of green manure in conjunction with chemical fertilizers did not yield an appreciable increase in crop yield. Among the fertilized crops, the control group exhibited the highest yield, registering at 6499 kilograms per hectare. It is worth noting that only in the instance of fertilized rapeseed did a marginal disparity in yield become evident. This observation underscores the limited efficacy of combining green manure and chemical fertilizers in augmenting crop productivity, with notable exceptions in the case of rapeseed (Table 6a).

Table 6a. The interaction of green manure and chemical fertilizer factors

Number	Green manure + Fertilized	Average (kg/ha)	Dif. (kg/ha)	Signif
1	Triticale F	5561	-938	OOO
2	Peas F	5891	-608	OO
3	Soy F	5913	-586	OO
4	Sunflower F	5970	-529	O
5	**Rapeseed F**	**6143**	-356	-
6	**Control F**	**6499**	-	

Note. F =Fertilized

In the context of chemically unfertilized crops, it is noteworthy that the application of green manure derived from peas led to the attainment of the highest yield, exhibiting a remarkable positive increment of 4389 kilograms per hectare (kg/ha) in comparison to the control group, which registered a yield of 4002 kg/ha. Conversely, the employment of green manure sourced from triticale resulted in the lowest yield observed at 2678 kg/ha, with the intermediate yields being obtained from the implementation of green manures derived from soy, sunflower, and rapeseed, yielding 3803 kg/ha, 2979 kg/ha, and 2960 kg/ha respectively. This data underscores the differential impact of distinct green manure sources on crop yield in the absence of chemical fertilization (Table 6b).

Table 6b. The interaction of green manure and chemical fertilizer factors

Number	Green manure + Unfertilized	Average (kg/ha)	Dif. (kg/ha)	Signif
1	Triticale UF	2678	-1325	OOO
2	**Peas UF**	**4389**	386	X
3	Soy UF	3803	-199	-
4	Sunflower UF	2979	-1023	OOO
5	Rapeseed UF	2960	-1043	OOO
6	Control UF	4002	-	
	CL (p 5%)	379		
	CL (p 1%)	536		
	CL (p 0.1%)	765		

Note. UF =Unfertilized

In the context of the interplay between green fertilizer application and fungicidal treatment, it is noteworthy that, across both the treated and untreated fungicide variants, the apex of yield was achieved within the control group, exhibiting a robust output exceeding 5200 kilograms per hectare in both instances. This observation underscores the significant influence of the control condition, irrespective of fungicide treatment, on maximizing crop yield.

Table 7a. The interaction of green manure and fungicide treatment factors

Number	Green manure + Treatment	Average (kg/ha)	Dif. (kg/ha)	Signif
1	Triticale T	4071	-1171	OOO
2	**Peas T**	**5061**	-182	-
3	Soy T	4821	-422	O
4	Sunflower T	4598	-645	OO
5	Rapeseed T	4545	-697	OO
6	Control T	5242	-	

Note. T =Treated

Table 7b. The interaction of green manure and fungicide treatment factors

Number	Green manure + Untreated	Average (kg/ha)	Dif. (kg/ha)	Signif
1	Triticale UT	4167	-1092	OOO
2	**Peas UT**	**5219**	-40	-
3	Soy UT	4896	-363	-
4	Sunflower UT	4352	-907	OOO
5	Rapeseed UT	4557	-702	OO
6	Control UT	5259	-	
	CL (p 5%)	394		
	CL (p 1%)	545		
	CL (p 0.1%)	756		

Note. UT =Unreated

CONCLUSION

In the culmination of our study, the inaugural year of experimentation with green manures yielded no immediate surge in crop yield. Nevertheless, it became manifest that our soils necessitated supplementary fertilization to fully unlock the advantages conferred by the incorporation of green manure. The dataset also disclosed a promising revelation - the application of green manures bolstered the disease resistance of wheat, portending enduring benefits for crop health.

Moreover, the incorporation of rapeseed and peas as green manure crops evinced a notable reduction in weeding, presenting an economical and pragmatic advantage for sustainable farming practices. Furthermore, when amalgamated with chemical fertilizers, the interplay with green manures showcased an augmented production capacity, accentuating the potential for a synergistic approach in maximizing crop output.

These discernments underscore the exigency of a holistic and integrated approach to agricultural methodologies, emphasizing the worth of harmonizing green manures with judicious fertilization strategies. As we persist in our exploration and refinement of these techniques, there lies prodigious potential to amplify both the productivity and sustainability of our agricultural systems, ultimately redounding to a more robust and efficient food production process.

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