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WASTE-BASED ORGANIC FERTILIZERS FOR IMPROVED PLANT NUTRITION AND YIELD RESPONSES

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Abstract

The increasing need to identify sustainable nutrient sources and reduce dependence on mineral fertilizers has intensified interest in organic materials derived from residual waste streams. This study evaluates several unconventional foliar fertilizers formulated from wheat bran, cornmeal, vinasse residue, bone glue and defatted sunflower meal, aiming to enhance plant nutrition. Chemical analyses of the concentrates revealed substantial macronutrient contents, with nitrogen ranging from 73.78 to 103.8 g/l, phosphorus from 14.48 to 18.09 g/l and potassium from 31.28 to 48.79 g/l, together with high levels of essential micronutrients such as manganese (545–1200 ppm) and iron (325–695 ppm). Field experiments conducted at the SCDA Podu Iloaiei on wheat and maize demonstrated significant yield responses across all tested variants. Wheat yields increased by 320–1040 kg/ha, while maize yields rose by 470–1240 kg/ha compared with foliar-unfertilized controls. Fertilizers based on wheat bran and cornmeal achieved the highest specific productivity, reaching up to 115.55 kg grain per liter in wheat and 82.66 kg per liter in maize. Additionally, nutrient-use efficiency improved by at least 20%, accompanied by a similar reduction in environmental pollution. These findings support the agronomic relevance and ecological benefits of integrating waste-derived fertilizers into sustainable crop management systems.

Key words: organic fertilizers, waste resources, foliar fertilization, nutrient-use efficiency, sustainable agriculture

INTRODUCTION

Increasing the bioaccessibility of nutrients from the soil and other natural sources by conventional and unconventional means, as well as increasing the levels of productive use of nutrients in larger harvests accompanied by the corresponding reduction of the polluting impact of chemical fertilization on the environment, are major goals of contemporary agriculture. Agricultural research conducted in our country

(Chiurciu et al, 2019, 2020; Dana et al, 2019) has shown that achieving these goals is possible to a significant extent by using, as part of current fertilization methods, fertilizer compositions containing hydrolysates from residual protein and gluco-protein sources, applicable to plant foliage in order to improve and correct nutrition.

The fertilizer compositions that are the subject of this topic are in line with this line and correspond to the national policy in the field. In addition, the new recipes and production technologies aim to use residual organic sources of raw materials existing in the country. The novelty and complexity of the proposed fertilizer compositions derive from the possibility of associating in fertilizer solutions macro (N, P, K) and microelements (Mn, Fe, Zn, Cu, Co, Mo) with physiologically active organic substances (amino acids, peptides, ureides), the latter contributing to a significant extent to the binding of microelements in soluble metal-protein complexes.

Internationally, there is a need to find new sources of fertilizers to meet the increasing food demand of a growing human population and alternatives to mined and synthetic fertilizers for the certified organic sector (Cabell et al, 2024).

In this regard, seaweed compost (Cabell et al, 2024), fish sludge (Brod et al, 2017) and bone meal mixed with ash (Brod et al, 2018) have been tested with encouraging results.

MATERIALS AND METHODS

Based on the results of previous research on the utilization of new sources of organic raw materials (wheat bran, cornmeal, Vinasses residual product, bone glue, defatted sunflower meal) in the composition of recipes for the production of some types of unconventional organic fertilizers, the results of chemical determinations carried out on the fertilizer compositions showed that they contain high amounts of macronutrients ranging for N between 73.78 and 103.8 g/l, for P between 14.48 and 18.09 g/l and for K between 31.28 and 48.79 g/l, which justifies their use in the prevention and treatment of nutritional diseases caused by the deficiency of these nutrients in agricultural crops. Regarding the concentrations of metal microelements determined in the fertilizer compositions, they vary within very wide limits, thus for Mn they are between 545 and 1200 ppm, for Fe between 695 and 325 ppm, for Zn between 387 and 435 ppm and for copper between 245 and 400 ppm – Tables 1-3.

The presence of high concentrations of the microelements Mn and Fe is also noted, which indicates the possibility of their effective use in the prevention and treatment of nutritional diseases caused by primary and secondary deficiencies of Mn and Fe in agricultural crops.

Table 1. Nutrient and organic matter contents in fertilizer compositions made from wheat bran

Concentrate components	TG1	TG2	TG3
Organic N, g/l	16.8	14.3	8.8
N-NO3, g/l	42.5	41.2	39.0
N-NH4, g/l	44.5	43.5	48.5
Total N, g/l	103.8	98.8	96.3
P, g/l	17.87	17.28	17.38
K, g/l	48.79	38.58	36.92
Mn, ppm	1050	860	970
Fe, ppm	450	620	690
Zn, ppm	431	400	400
Cu, ppm	400	370	330

Source: Authors' data (SCDA Podu Iloaiei field experiment)

The rigorous field testing activity with plants of the fertilizer compositions was carried out in the experimental field at SCDA Podul Iloaiei, Iași County.

The experiments were located in the field according to the randomized block method, for each experimental variant a minimum number of 4 plots-repetitions with a harvestable area of 30 m^2 was ensured.

Table 2. Nutrient and organic substance contents in fertilizer compositions made from cornmeal

Concentrate components	M1	M2	M3
Organic N, g/l	4.78	9.64	5.65
N-NO3, g/l	24	33	37.5
N-NH4, g/l	45.78	36.5	38.5
Total N, g/l	73.78	79.14	81.6
P, g/l	18.09	17.48	16.90
K, g/l	38.25	34.10	32.86
Mn, ppm	1200	545	1135
Fe, ppm	650	375	695
Zn, ppm	435	387	435
Cu, ppm	285	321	380

Source: Authors' data (SCDA Podu Iloaiei field experiment)

Table 3. Nutrient and organic substance contents in fertilizer compositions made from Vinasses, bone glue and defatted sunflower meal

Concentrate components	V1	V2	V3	V4
Organic N, g/l	6.65	5.11	8.4	4.79
N-NO3, g/l	43.20	45.42	40.82	32.62
N-NH4, g/l	42.14	43.72	39.42	37.02
Total N, g/l	92.26	94.25	88.64	74.43
P, g/l	17.64	17.49	17.46	14.48
K, g/l	31.70	32.28	32.85	31.28
Mn, ppm	910	700	1050	1075
Fe, ppm	600	325	375	500
Zn, ppm	435	435	435	435
Cu, ppm	330	240	400	400

Source: Authors' data (SCDA Podu Iloaiei field experiment)

The foliar treatments were applied to the wheat crop (Eliana PB 2 variety) and to the corn crop (HS Oana).
During the entire vegetation period of the plants, three foliar treatments were applied in concentrations of 1% and in doses of 300 l - 500 l solution / ha / application.
The soil type in the experiments was cambic chernozem with the following properties: pH-7.2, PAL-36 ppm, KAL-245 ppm, Nt-0.165, humus-3.36%.

RESULTS AND DISCUSSIONS

In wheat cultivation (Tables 4-5) it is found that foliar treatments ensured significant yield increases in all cases statistically analyzed. The production increases recorded in the foliar fertilized variants varied between 320 (110%) and 1040 (133%) kg/ha compared to the soil fertilized control.
Regarding the agronomic and economic effectiveness of foliar fertilizers, it is found that:
- foliar fertilizers obtained based on defatted sunflower meal, vinasse and bone glue ensured a production increase of 320-1000 kg/ha (110-132%) and a specific increase of 35.55-111.11 kg of spore grains/ l of fertilizer applied (Fig. 1).

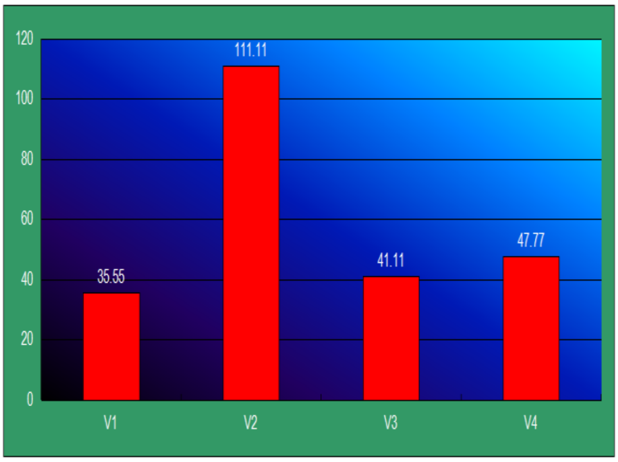

Figure 1. Specific yield increases (kg yield / l of foliar fertilizer applied) of Vinasa foliar fertilizers, applied to wheat crop, Eliana PB2 variety
Sources: Own design based on experimental results

- foliar fertilizers obtained based on wheat bran ensured a production increase of 490-1040 kg/ha (112-133%) and a specific increase of 54.44-115.55 kg of grain/ l of fertilizer applied (Fig. 2).

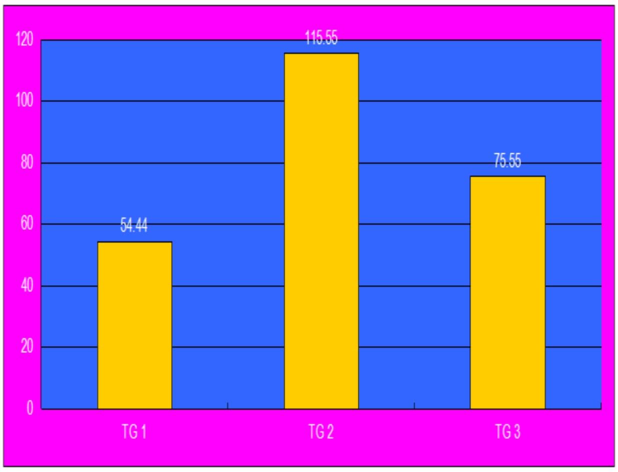

Figure 2. Specific yield increases (kg yield/ l of foliar fertilizer applied) of foliar fertilizers compositions made from wheat bran, applied to wheat crop, Eliana PB2 variety
Sources: Own design based on experimental results

- foliar fertilizers obtained from cornmeal provided a production increase of 360-480 kg/ha (111-115%) and a specific increase of 40.00-53.33 kg of grain/liter of fertilizer applied (Fig. 3).

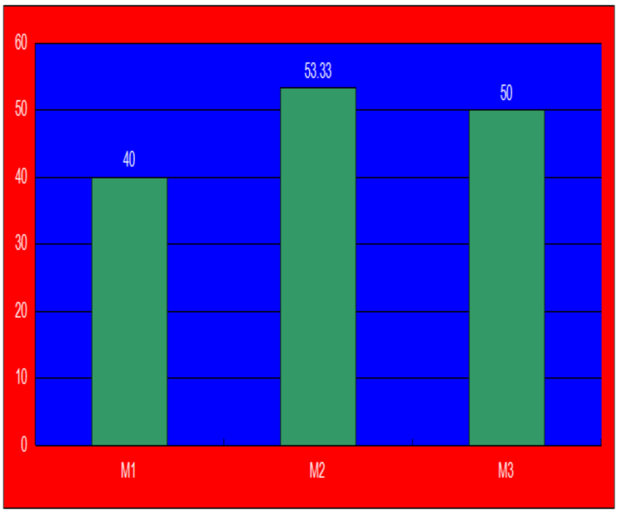

Figure 3. Specific yield increases (kg yield/ l of foliar fertilizer applied) of foliar fertilizers compositions made from cornmeal, applied to wheat crop, Eliana PB2 variety
Sources: Own design based on experimental results

The best results were obtained with the TG2 fertilizer, which provided the highest production increase (1040 kg/ha increase), followed by the V2 fertilizer (1000 kg/ha increase) and TG3 (680 kg/ha increase). Among the foliar fertilizers, the best utilized were the fertilizers obtained based on wheat bran, which ensured distinctly significant production increases for all foliar treatment variants compared to the unfertilized foliar control. The economic effectiveness of foliar treatments, embodied in the specific yield increase achieved/liter of fertilizer applied, indicates that TG-type preparations are effective.

In corn cultivation, the increase in grain production provided by foliar fertilizers (Tables 6-7) was between 470 (109%) and 1240 (125%) kg/ha compared to the soil-fertilized control. Foliar fertilizers obtained based on defatted sunflower meal, vinasse and bone glue ensured a production increase of 470-880 kg/ha (109-118%) and a specific increase of 31.33-58.66 kg of grain/liter of fertilizer applied (Fig. 4).

Figure 4. Specific yield increases (kg yield/ l of foliar fertilizer applied) of Vinasa foliar fertilizers, applied to maize crop, HS Oana hybrid
Sources: Own design based on experimental results

Foliar fertilizers obtained based on wheat bran ensured a production increase of 910-1090 kg/ha (118-122%) and a specific increase of 60.66-72.66 kg of grain/liter of fertilizer applied (fig. 5).

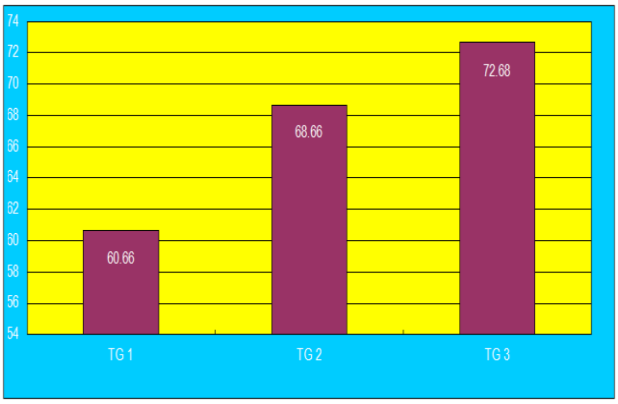

Figure 5. Specific yield increases (kg yield/ l of foliar fertilizer applied) of foliar fertilizers compositions made from wheat bran, applied to maize crop, HS Oana hybrid
Sources: Own design based on experimental results

Foliar fertilizers obtained from cornmeal have a grain yield increase of 1050-1240 kg/ha (121-125%) and a specific yield increase of 70.00-82.66 kg grain yield/liter of fertilizer applied (Fig. 6).

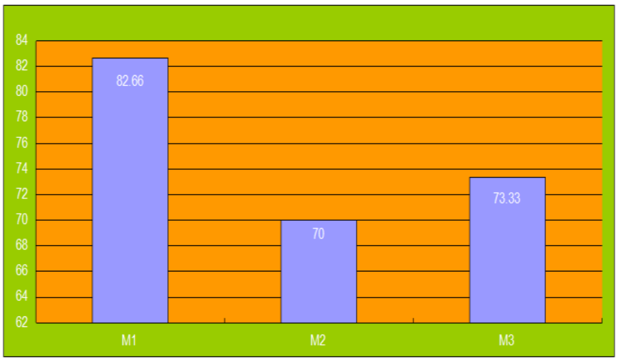

Figure 6. Specific yield increases (kg yield/ lit of foliar fertilizer applied) of foliar fertilizers compositions made from cornmeal, applied to maize crop, HS Oana hybrid
Sources: Own design based on experimental results

Table 4. Agronomic effectiveness of new foliar fertilizers obtained based on hydrolysates from defatted sunflower meal, vinasse and bone glue, applied to wheat crop, Eliana PB2 variety, cultivated on cambic chernozem from SCDA Podu Iloaiei

Treatments	Production of grains kg/ha	Yield increases compared to C1		Yield increases compared to C2	
		kg/ha	%	kg/ha	%
N_0 P_0 Foliar non-fertilized control-C1	2720	-	100	-	-
N_{80} P_{60} Foliar non-fertilized control-C2	3110	390^{x}	114	-	100
N_{80} P_{60} + Vinasa 1	3430	710^{xxx}	126	320^{x}	110
N_{80} P_{60} + Vinasa 2	4110	1390^{xxx}	151	1000^{xxx}	132
N_{80} P_{60} + Vinasa 3	3480	760^{xxx}	128	370^{x}	112
N_{80} P_{60} + Vinasa 4	3540	820^{xxx}	130	430^{x}	114

LSD 5% 317
1% 439
0.1% 606

Source: Authors' data (SCDA Podu Iloaiei field experiment)

Table 5. Agronomic effectiveness of new foliar fertilizers obtained from hydrolysates of wheat bran and corn grits, applied to wheat crop, Eliana PB2 variety, cultivated on cambic chernozem from SCDA Podu Iloaiei
Source: Authors' data (SCDA Podu Iloaiei field experiment)

Treatments	Production of grains kg/ha	Yield increases compared to C1		Yield increases compared to C2	
		kg/ha	%	kg/ha	%
N_0 P_0 Foliar non-fertilized control-C1	2720	-	100	-	-
N_{80} P_{60} Foliar non-fertilized control-C2	3110	390^{x}	114	-	100
N_{80} P_{60} + TG 1	3500	780^{xxx}	128	490^{xx}	112
N_{80} P_{60} + TG 2	4150	1430^{xxx}	152	1040^{xxx}	133
N_{80} P_{60} + TG 3	3790	1070^{xxx}	139	680^{xxx}	121
N_{80} P_{60} + M 1	3470	750^{xxx}	127	360^{x}	111
N_{80} P_{60} + M 2	3590	870^{xxx}	132	480^{xx}	115
N_{80} P_{60} + M 3	3560	840^{xxx}	131	450^{xx}	114

LSD 5% 301
1% 410
0.1% 554

Table 6. Agronomic effectiveness of new foliar fertilizers obtained based on hydrolysates from defatted sunflower meal, vinasse and bone glue, applied to corn crop, HS Oana, cultivated on cambic chernozem from SCDA Podu Iloaiei

Treatments	Production of grains kg/ha	Yield increases compared to C1		Yield increases compared to C2	
		kg/ha	%	kg/ha	%
N_0 P_0 Foliar non-fertilized control-C1	4320	-	100	-	-
N_{60} P_{60} Foliar non-fertilized control-C2	4950	630^{xx}	114	-	100
N_{60} P_{60} + Vinasa 1	5420	1100^{xxx}	125	470^{x}	109
N_{60} P_{60} + Vinasa 2	5780	1460^{xxx}	134	830^{xx}	117
N_{60} P_{60} + Vinasa 3	5490	1170^{xxx}	127	540^{x}	111
N_{60} P_{60} + Vinasa 4	5830	1510^{xxx}	135	880^{xx}	118

LSD 5% 426
1% 619
0.1% 987

Source: Authors' data (SCDA Podu Iloaiei field experiment)

Table 7. Agronomic effectiveness of new foliar fertilizers obtained from hydrolysates of wheat bran and corn grits, applied to corn crop, HS Oana, cultivated on cambic chernozem from SCDA Podu Iloaiei

Treatments	Production of grains kg/ha	Yield increases compared to C1		Yield increases compared to C2	
		kg/ha	%	kg/ha	%
N_0 P_0 Foliar non-fertilized control-C1	4320	-	100	-	-
N_{60} P_{60} Foliar non-fertilized control-C2	4950	630	114	-	100
N_{60} P_{60} + TG 1	5860	1540^{xxx}	135	910^{x}	118
N_{60} P_{60} + TG 2	5980	1660^{xxx}	138	1030^{x}	120
N_{60} P_{60} + TG 3	6040	1720^{xxx}	140	1090^{xx}	122
N_{60} P_{60} + M 1	6190	1870^{xxx}	143	1240^{xx}	125
N_{60} P_{60} + M 2	6000	1680^{xxx}	142	1050^{x}	121
N_{60} P_{60} + M 3	6050	1730^{xxx}	140	1100^{xx}	122

LSD 5% 800
1% 1090
0.1% 1470

Source: Authors' data (SCDA Podu Iloaiei field experiment)

Among the foliar fertilizers, the best production results were obtained with the TG and M types, preparations that also ensured the highest specific yield increase/liter of fertilizer applied.

CONCLUSIONS

Internationally, there is great concern to find new sources of organic matter that can be used as fertilizers.

The use of these organic sources also determines a good recycling of waste resulting from different industrial sectors.

The new types of foliar fertilizers ensure:

- in wheat crops, yield increases by 320 (110%) - 1040 (133%) higher than the unfertilized foliar control;
- in corn crops, yield increases of 470 (109%) - 1240 (125%) higher than the unfertilized foliar control;
- productive use of soil nutrients in the crop by at least 20% higher;
- chemical pollution effects reduced by approximately 20% compared to classic mineral fertilizers;
- increasing the quality of agricultural products by balancing their macro and micronutrient content.

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