



Research Article

The combination of poultry litter, vivianite powder and mycorrhizae: A suitable natural fertilizer for improving nutritional values of soybean (*Glycine max* Linn. Merril)

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Abstract

This study evaluated the effect of combining various natural fertilizers on soybean nutritional values. The field study followed a randomized complete block design with 11 treatments and 03 replications. Treatments were applied to growing soybean plants: 30 g of poultry litter (F1), 60 g of poultry litter (F2), combination of 10 g of mycorrhizae + 10 g of vivianite powder (MP), combination of 10 g of mycorrhizae + 30 g of poultry litter (MF1), combination of 10g of mycorrhizae + 60 g of poultry litter (MF2), 10 g of vivianite powder +30 g of poultry litter (PF1), 10g of vivianite powder + 60 g of poultry litter (PF2), 10 g of mycorrhizae +10g of vivianite powder +30 g of poultry litter (MPF1), 10 g of mycorrhizae +10 g of vivianite powder +60 g of poultry litter (MPF2), chemical fertilizer (T+) and plants without fertilizers (T-). Seeds physical characteristics, such as thickness and weight were assessed. Evaluated seeds chemical properties were: protein content, oil content and total sugar content. Results show that seed weight from MPF2 treated plants was 1.43, and 3.64 times higher than those from T- and T+ treated plants respectively. MPF2 treatment increased the protein content of soybean seeds by 135.80% and 262.76 % compared to T- and T+ treatments respectively. In conclusion, the production and application of the mixture of 10 g of mycorrhizae + 10 g of vivianite powder + 60 g poultry litter per hole at sowing for soybean growing would contribute to improve soybean nutritional values, and valorize the employment of local material in organic farming, as well as to protect the environment.

1. Introduction

In the Northern Region of Cameroon, cereals are considered the basic foods for humans and some animals. Even though they provide important calories, they remain deficient in protein [1]. Legumes are excellent supplement in protein for a diet rich in cereal because they can provide up to 38% of proteins [2]. Soybeans in particular, are major source of high-quality protein and oil [3], and the quality of soybean seed is often determined by seed protein, oil, fatty acid, and mineral content. Therefore, improving soybean seed quality in the

Northern Region of Cameroon is crucial to improving human and animal nutrition. In general, oil and protein comprise almost 60% of the total storage of soybean seed [4]. There is a negative correlation between the oil and protein contents of soybean seeds [5]. Previous research has shown a significant effect of agricultural practices on protein and oil contents of soybean seeds [6].

The study of several authors [7-9] revealed that natural fertilizers improve soil fertility and therefore plants productivity. In this regard, the study [10] was

aimed to improve soybean production by using natural fertilizers, that found the supply of the following combination, 10 g of mycorrhizae + 10 g of vivianite powder + 60 g of poultry litter (MPF2) per hole, better improved soybean growth and seed yield under high Guinean Savannah climate of Adamawa Cameroon. However, no work has been carried out on the nutritional values of soybean seeds from treated MPF2 soybean plants. This lack of data seems to be a handicap for the appreciation of MPF2 natural fertilizer for improving the nutritional values of soybean seeds.

The mycorrhizae are symbiotic associations between mycorrhizal fungi and plant roots. This bio-fertilizer improves plant productivity by promoting plant hydromineral nutrition [11]. Vivianite is an iron oxide and phosphate. The chemical formula of vivianite is $\text{Fe}_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$. The positive effects of vivianite powder on crop productivity have been demonstrated [9, 10]. Phosphorus is one of the essential macronutrients for plant growth and development. It is the second most important macroelement after nitrogen [13]. The poultry litter is a mixture of the substrate, usually wood chips, with bird droppings, feathers, and leftover food. Due to its composition in nutrient elements and availability at low cost in Ngaoundere (Cameroon), it can be used by farmers for soil fertilization and thus the crop nutritional values. Therefore, the study aimed to improve the physico-chemical properties of soybean seeds through improving soil fertility by using natural fertilizers.

2. Materials and methods

2.1 Soybean seeds and their origin

Seeds of SJ 235 variety of soybean were used for this study (Fig. 1). These seeds were harvested in the experimental farm of the Laboratory of Biodiversity and Sustainable Development of the University of Ngaoundere (Cameroon) during the 2018 and 2019 cropping seasons. The pH of soybean growing soil was acidic (4.30 ± 0.01). N was the main component of the cropped soil. N, P, Ca and Mg contents (g/100 g of dry growing soil) were 4.23 ± 0.59 , 0.41 ± 0.02 , 0.49 ± 0.00 and 0.10 ± 0.02 respectively [10]. This soybean variety was chosen for its early germination, its adaptability to the rainy season and its short

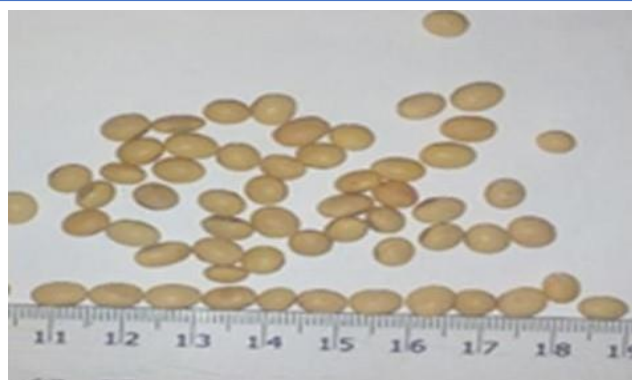


Figure 1. Seeds of SJ 235 variety of *Glycine max* Linn. Merrill.

reproduction cycle (110 days). The variety that has a short reproduction cycle is advantageous for farmers because they may have several harvests per year if they have the possibility to practice off-season cropping [14]. Seeds were first cleaned by hand picking to discard the damaged ones, packaged and stored for physico-chemical analysis. Regarding field study, a randomized complete block experimental design with 11 treatments and three replications were used. The seeds used in this study were harvested at 110 days after sowing from the soybean plants subjected to the following treatments: 30 g of poultry litter (F1), 60 g of poultry litter (F2), combination 10 g of mycorrhizae + 10 g of vivianite powder (MP), combination of 10 g of mycorrhizae + 30 g of poultry litter (MF1), combination of 10 g of mycorrhizae + 60 g of poultry litter (MF2), 10 g of vivianite powder + 30 g of poultry litter (PF1), 10 g of vivianite powder + 60 g of poultry litter (PF2), 10 g of mycorrhizae + 10 g of vivianite powder + 30 g of poultry litter (MPF1), 10g of mycorrhizae +10g of vivianite powder +60 g of poultry litter (MPF2), chemical fertilizer (T+), plants without fertilizers (T-). The mycorrhizae used were supplied by the Laboratory of Soil and Microbiology of the Biotechnology Center of the University of Yaounde I, Cameroon. Selected isolates were multiplied by peanut and sorghum plants (host plants) and tested on maize and sorghum. It contains infective propagules and spores of three genus *Gigaspora*, *Glomus* and *Scutellospora* species with a concentration of approximately 20 spores/g of substrate.

Vivianite was sampled from the Hangloa Basin located from 25 km of the Northwest of the city of

Ngaoundere (Cameroon). The chemical analyses of the powder derived from these rocks gives the following composition: Fe_2O_3 (68.72%), P_2O_5 (9.17%), Al_2O_3 (7.72%), and SiO_2 (9.67%). Thus, the total phosphorus was estimated at about 671.50 mg/kg while the assimilated phosphorus was around 81.13 mg/kg. Phosphate contained in this mineral can be solubilized.

Poultry litter from a henhouse located near the campus of the University of Ngaoundere was collected from 8 to 9 am daily according to its availability and then stored in 50 kg bag before being transported to the experimental area using a rickshaw.

The chemical fertilizer was bought on the local market in Ngaoundere. The main nutrients of the fertilizer are nitrogen (N), phosphorus (P), and potassium (K). It is referred to as NPK (12-24-12) chemical fertilizer which mean that contained 12% N, 24% P_2O_5 , and 12% K_2O .

2.2 Determination of seeds physical characteristics

The physical characteristics of 100 seeds such as thickness and weight were evaluated. The seeds weight was evaluated using an electronic balance (Sartorius, Prodilab, France), with 0.001 sensitivity. Thickness was measured using micrometer gauge reading (0.01 mm sensitivity).

2.3 Assessment of chemical properties of soybean seeds

The evaluated chemical properties of the seeds included protein, oil and the total sugar contents.

Concerning the evaluation of the protein content, the seeds were decorticated and milled into fine powder, of which, 5 g of powder was weighed in a crucible and conditioned to oven-drying at 105 °C, until a constant weight was obtained. Nitrogen content was determined after sulfuric acid digestion and colorimetric determination of nitrogen using the method described by [15]. Determination of the organic matter content was done by subjecting the powder at 550 °C for 3h [16] and the ash residual was used for some mineral determination according to [17]. The conventional conversion coefficient of nitrogen into protein (6.25) was used to determine the protein content [18]. The crude protein content is therefore evaluated: $6.25 \times Q$ (g / 100 g DM) where Q is the soybean seeds nitrogen contain.

In determining the soybean seeds oil content, the seeds were decorticated and milled into fine powder. 5 g of the powder were then oven-dried at 105°C for 1 hour. The oil was extracted using hexane as a solvent [19]. In the procedure, samples were refluxed for 6 hours in mild temperature (60°C) in a Soxhlet extractor. After that, the solvent was then evaporated using a rotary evaporator. Finally, the extracted oil was kept in an oven at 60°C for 30 min before weighing for accuracy.

The total sugar contents were determined according to [20]. The optical density was read at 540 nm with a spectrophotometer. The average of three tests was considered as the results.

2.4 Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) and when the differences were significant ($p < 0.05$), a Duncan multiple range test was performed to compare means. The Stagraphic Plus Program version 5.0 was used for this purpose.

3. Results and discussion

3.1 Seed physical characteristics

Studied seeds physical parameters were weight and thickness. Table 1 shows the weight and thickness of 100 seeds of soybean depending on fertilizers and the cropping years. The analysis of variance (ANOVA) showed that there was a highly significant difference ($P < 0.01$) between fertilizers relative to the physical characteristics of soybean seeds. The weight of 100 soybean seeds varied from 3.00 ± 0.32 g for seeds harvested in the non-treated plot (T-) to 11.51 ± 0.42 g for seeds from treated plants with the combination of 10 g mycorrhizae + 10 g vivianite powder + 60 g poultry litter (MPF2). Seeds from the MPF2 treatment weighed more than those from the other treatments and were 3.65 times heavier than those from the T- plot.

The lowest seed thickness (2.00 ± 0.84 mm) was from T- plant in 2019 (cropping year), while the highest value of this parameter (2.90 ± 0.14 mm) was recorded from seeds harvested on a treated plot with MPF2 fertilizer in the 2018 cropping season. Overall, the thickness of MPF2 seeds was 1.43 times greater than that of T- seeds.

Table 1. Physical characteristics of the soybeans seeds according to the fertilizers and the year of experimentation

Fertilizers	2018 Cropping season		2019 Cropping season		M ± SD	
	W100S (g)	TH (mm)	W100S(g)	TH (mm)	W100S (g)	TH (mm)
T-	3.00±0.32	2.00±0.13	3.22±0.23	2.00±0.84	3.11±0.27 ^a	2.00±0.48 ^a
T+	3.55±0.39	2.27±0.74	3.55±0.25	2.25±0.90	3.55±0.32 ^a	2.26±0.82 ^{ab}
F1	10.81±0.47	2.26±0.10	10.48±0.31	2.24±0.82	10.64±0.39 ^{bcd}	2.25±0.46 ^{ab}
F2	10.86±0.30	2.02±0.80	10.52±0.25	2.02±0.11	10.69±0.27 ^{bcd}	2.02±0.45 ^a
MP	10.49±0.41	2.22±0.14	10.16±0.45	2.18±0.11	10.32±0.43 ^{bc}	2.20±0.12 ^{ab}
PF1	10.9±0.23	2.3±0.82	10.57±0.41	2.22±0.77	10.73±0.32 ^{cd}	2.26±0.79 ^{ab}
PF2	11.17±0.20	2.02±0.12	11.17±0.44	2.02±0.91	11.17±0.32 ^{cd}	2.02±0.51 ^a
MF1	10.52±0.28	2.38±0.10	10.18±0.20	2.32±0.15	10.35±0.24 ^{bcd}	2.35±0.12 ^b
MF2	10.43±0.42	2.58±0.80	10.1±0.30	2.42±0.11	10.26±0.36 ^b	2.50±0.45 ^b
MPF1	10.74±0.46	2.21±0.13	10.39±0.22	2.2±0.74	10.56±0.34 ^{bcd}	2.21±0.43 ^{ab}
MPF2	11.18±0.34	2.90±0.14	11.51±0.42	2.82±0.97	11.34±0.38 ^d	2.86±0.55 ^c
M ± SD	9.42±0.34	2.29±0.36	9.26±0.31	2.24±0.58	9.34±0.32	2.26±0.47

F1: 31g of poultry litter, F2: 62 g of poultry litter, MP: combination 10g of mycorrhizae + 10g of vivianite powder, MF1: combination 10 g of mycorrhizae + 30 g of poultry litter, MF2: combination 10 g of mycorrhizae + 60 g of poultry litter, PF1: 10 g of vivianite powder +30 g of poultry litter, PF2: 10 g of vivianite powder + 60 g of poultry litter, MPF1: 10 g of mycorrhizae +10 g of vivianite powder +30 g of poultry litter, MPF2: 10 g of mycorrhizae + 10 g of vivianite powder + 60 g of poultry litter, T+: chemical fertilizer, T-: plants without fertilizers, W100S: weight of 100 seeds, TH: thickness. Values in column followed by different letters are significantly different at the 5% threshold.

3.2 Seeds chemical properties

The studied chemical properties include protein, lipid, sugar and ash contents (Table 2). The statistical analyses revealed that used fertilizers significantly increased ($p < 0.05$) the soybean nutritional values.

The lowest protein content ($27.00 \pm 0.35\%$) was from the seeds harvested on non-treated plot (T-) during the 2019 cropping season, while the highest value of this parameter ($48.33 \pm 0.38\%$) was recorded on seeds from treated MPF2 (10 g of mycorrhizae + 10 g of vivianite powder + 60 g of poultry litter) plants grown in 2018.

The total sugar content ranged between $17.33 \pm 0.22\%$ for seeds from T- plants in the 2019 cropping year to $39.00 \pm 0.49\%$ for seeds harvested on MPF2 plants in 2018. Overall, the total seeds sugar contained from MPF2 plots was 2.17 times greater than that of the seeds from T- plants.

The highest total lipid content ($20.66 \pm 0.56\%$) was obtained on seeds from MPF2 plots in the 2018 cropping season, while the lowest value ($15.33 \pm 0.17\%$) of this parameter was recorded on T- plants in 2019. Globally, the total seed lipid content from MPF2 plants was 1.25 times higher than that of T- plants.

Total ash content of soybeans ranged from $2.66 \pm 0.90\%$ in the 2019 cropping season to $9.00 \pm 0.50\%$ in 2018. However, the MPF2 treatment generated an increase in ash content at 79.85 % compared to T- seeds.

It is observed in the present study that the average weight of 100 seeds ranged between 3.11 ± 0.27 g for non- treated plants (T-) and 11.34 ± 0.38 g for fertilized plants by 10 g of mycorrhizae + 10 g of vivianite powder + 60 g of poultry litter (MPF2). This result does not corroborate data reported by [21], who studied the effect of vermicompost on the growth of soybean at Indonesian Methodist University and found that the weight of 100 seeds ranged between 11.53 g and 14.10 g. The weight is an indicator of the seed’s nutrient contents. In fact, the seeds that exhibited the highest weight would have the best nutritional values. It is reported in this study that MPF2 fertilizer enhanced seeds weigh relative to other used fertilizers, suggesting that these seeds were richer in nutrients. Furthermore, several authors reported [7, 22] that there was a positive correlation between seeds weight and thickness.

In this study, the average thickness of the soybean seeds from both the 2019 and 2020 harvest seasons is 2.26 ± 0.47 mm. This result recorded on thickness

Table 2. Chemical properties of soybeans according to fertilizers and harvest season

Fertiliser	2018 Cropping season				2019 Cropping season				M ± SD			
	TP%	TST%	TLT%	TAC%	TP%	TST%	TLT%	TAC%	TP%	TST%	TLT%	TAC%
T-	27.33±0.80	17.66±0.92	16.00±0.22	4.00±0.70	27.00±0.35	17.33±0.22	15.33±0.17	2.66±0.90	27.16±0.57 ^a	17.50±0.57 ^a	15.66±0.19 ^a	3.33±0.80 ^a
T+	34.66±0.77	27.33±0.39	19±0.20	5.00±0.18	33.66±0.42	26.66±0.32	18.00±0.27	5.66±0.12	34.16±0.59 ^{cd}	27.00±0.35 ^{ef}	18.50±0.14 ^{de} fg	5.33±0.15 ^{bcdef}
F1	36.66±0.50	30.00±0.72	17.33±0.37	6.33±0.52	35.00±0.53	28.66±0.63	16.00±0.31	5.66±0.41	35.83±0.51 ^{de} fg	29.33±0.67 ^{gh}	16.66±0.34 ^{ab}	6.00±0.46 ^f
F2	36.66±0.33	26.33±0.50	19.33±0.43	5.33±0.47	35.00±0.40	22.33±0.43	18.00±0.43	4.33±0.33	35.83±0.36 ^{def}	25.66±0.46 ^{de}	18.66±0.46 ^{ef} g	4.83±0.40 ^{bcd}
MP	38.66±0.18	24.33±1.15	18.66±0.76	6.33±0.57	37.00±0.82	23.00±0.79	17.33±0.54	5.33±0.40	37.80±1.00 ^{gh}	23.66±0.97 ^{cd}	18.00±0.63 ^{bcde}	5.83±0.48 ^{def}
PF1	42.33±0.97	21.33±1.12	17.66±0.49	6.00±0.39	40.66±0.45	20.00±0.66	16.33±0.42	5.00±0.34	41.50±0.7 ^{ijk}	20.66±0.89 ^b	17.00±0.45 ^{abcd}	5.50±0.73 ^{bcdef}
PF2	40.33±0.54	23.66±0.65	18.66±0.35	5.33±0.21	38.66±0.56	22.33±0.70	17.33±0.50	4.33±0.28	39.50±0.55 ^{ij}	23.00±0.67 ^c	18.00±0.42 ^{bcdef}	4.83±0.24 ^{bcde}
MF1	34±1.16	30.33±1.13	19.33±0.99	4.33±0.52	32.33±0.62	29.00±0.76	18±0.35	4.66±0.22	33.16±0.89 ^{bc}	29.66±0.94 ^{ghi}	18.66±0.67 ^{ef} g	4.50±0.37 ^b
MF2	35.33±1.00	29±1.11	17.33±0.37	5.00±0.27	33.66±0.51	27.66±0.52	16±0.30	4.33±0.18	34.50±0.75 ^{cde}	28.33±0.81 ^{fg}	16.66±0.33 ^{abc}	4.66±0.22 ^{bc}
MPF1	32±0.37	31.33±0.42	19.66±0.40	6.33±0.29	30.33±0.32	30.00±0.51	18.33±0.39	5.66±0.26	31.16±0.34 ^f	30.66±0.46 ^{hij}	19.00±0.39 ^{ef} g	6.00±0.27 ^f
MPF2	48.33±0.38	39.00±0.49	20.66±0.56	9.00±0.50	46.00±0.47	37.00±0.47	18.66±0.52	6±0.37	47.16±0.42 ⁱ	38.00±0.48 ^k	19.66±0.54 ^{gh}	7.50±0.43 ^s
M±SD	36.99±0.72 ^b	27.30±0.78 ^b	18.51±0.47 ^a	5.72±0.42 ^b	35.39±0.49 ^a	26.06±0.54 ^a	17.21±0.38 ^b	4.87±0.34 ^a	36.16±0.60	26.68±0.66	17.86±0.42	5.29±0.38

F1: 31 g of poultry litter, F2: 62 g of poultry litter, MP: combination 10 g of mycorrhizae + 10 g of vivianite powder, MF1: combination 10 g of mycorrhizae + 30 g of poultry litter, MF2: combination 10 g of mycorrhizae + 60 g of poultry litter, PF1: 10 g of vivianite powder +30 g of poultry litter, PF2: 10 g of vivianite powder + 60 g of poultry litter, MPF1: 10 g of mycorrhizae +10 g of vivianite powder + 30 g of poultry litter, MPF2: 10 g of mycorrhizae +10 g of vivianite powder + 60 g of poultry litter, T + : chemical fertilizer, T-: plants without fertilizers, TP: total protein content, TST: total sugar content, TLT: total lipid content, TAC: total ash content M ± SD: Mean±Standard deviation. Values in column followed by different letters are significantly different at the 5 % threshold.

does not corroborate data with the literature [23] that indicated the soybean seed thickness was 5.50 ± 0.29 mm. Overall, the MPF2 treatment better improved the physical characteristics of soybean seeds. Indeed, this MPF2 treatment is a mixture of vivianite powder, which is a source of phosphorus [12], a compost derived from the poultry litter which is rich in various mineral elements [10] and mycorrhizae. One of the actions of mycorrhizae would be associated with the solubilization of phosphate that would be more assimilable as the result of the excretion of acid phosphatase in the rhizosphere. It is possible that mycorrhizae, by hydrolyzing phosphorylated mineral compounds, allow plants to uptake the phosphorus from a source that was not directly accessible to them [24].

The combined effect of mycorrhizae, vivianite powder and compost would have allowed the soybean plants to absorb more nutrients necessary for their growth and development, and consequently to improve the seeds physical characteristics. Furthermore, several authors reported [7, 18, 25] that the plants chemical properties varied according to the growing substrate. In this regard, it would be interesting to study the effects of fertilizers on the soybean seeds component in order to determine the fertilizer that better improves the nutritive values of soybeans.

The protein contents of soybean seeds recorded in the present study partly corroborate the data found in the literature. Indeed, [26] studied the variation in protein contents of collected domestic and foreign soybean germplasm in Korea and found that the variation in protein content of this food legume was between 28.70% and 44.50%. Overall, the MPF2 treatment increased the soybean seed protein content up to 135.80% compared to T- treatment. The beneficial effect of mycorrhizae on the protein content of the soybean seeds observed in this study was in accordance with the finding of [27], who revealed that the mycorrhizal fungi enhanced nitrogen assimilation by the plant, and consequently stimulated protein biosynthesis.

It was reported in this study that total sugar content of soybean seeds varied from $17.50 \pm 0.57\%$ for T-seeds to $8.00 \pm 0.48\%$ for MPF2 seeds, this result obtained on seeds sugar content partially corroborate

data found in the report [28] who studied the genetic and phenotypic characterization of soybean landraces collected from the Zhejiang Province in China and revealed that the total seeds sugar content ranged from 1.01% to 14.05%, with a mean of 7.05%. Sugars play a structural role and are involved in digestion and immune response.

Data obtained on lipid content as well as on oil content of soybean seeds in this work partially corroborate those reported by [29] who reported that the lipid content of this legume were 18%. Lipids are indicators of energy storage and play a structural role. The soybean oil is rich in essential fatty acids. It contributes to a low level of cholesterol in the blood and therefore to a low risk of heart disease.

The beneficial effect of mycorrhizae on the ash content of soybean seeds observed in this work corroborates the data found in the literature. It was revealed [30] that mycorrhizae facilitate the uptake of water and mineral elements from the soil due to the high soil coverage by the mycelial network. Ash is a basic residue from the incineration of organic or mineral materials. The ash content of a reserve organ is an indicator of the quantity of the trace elements absorbed by the plant. Ash is made up of mineral elements that maintain the acid-base balance and participate in most biochemical reactions of an organism.

In general, it appears from this study that the MPF2 treatment better improves the physical characteristics as well as the nutritional values of soybeans. This finding is not surprising, because the beneficial effect of mycorrhizae, the rock powder and the organic amendments on the improvement of plant nutritional values has been demonstrated. Indeed, the MPF2 treatment used in this study as a mixture of mycorrhizal fungi, vivianite powder and poultry litter has acted in the same manner.

Regarding the mycorrhizae mechanism of action, mycorrhizal fungi can be associated with the soil rhizobia to facilitate the atmospheric nitrogen fixation. In addition, mycorrhizal fungi could explore a large volume of soil and associate with certain soil bacteria to dissolve the soil minerals, making them available for the plant absorption. Moreover, the vivianite used in this study had a high percentage of solubility and its mineralogical composition was

estimated as follows: Fe₂O₃ (68.72%), P₂O₅ (9.17%), Al₂O₃ (7.72%) and SiO₂ (9.67%) [12]. The poultry litter used in this work is organic amendment rich in various mineral elements [10].

The beneficial effect of the MPF2 treatment on the improvement of physical characteristics and nutritive values of soybeans would be justified by the fact that the combination of the utilities of the components of this fertilizer (mycorrhizal fungi, vivianite powder and poultry litter) would have improved the hydromineral nutrition of soybean plants, with the positive effect in stimulating the biosynthesis of the primary metabolites and their storage in the seeds. However, it would be interesting to study the influence of MPF2 fertilizer on the kinetics of mineral uptake by soybean in order to better appreciate the effects of this fertilizer on the biosynthesis of nutrients in the seeds of this food crop.

4. Conclusions

Physico-chemical properties of soybean seeds vary depending on the growing substrate. The weight of 100 seeds from fertilized plants by 10 g of mycorrhizae +10 g of vivianite powder + 60 g of poultry litter (MPF2) were 1.43 and 3.64 times higher than those from non-treated plants and fertilized plants by chemical fertilizer respectively. 10 g of mycorrhizae +10 g of vivianite powder + 60 g of poultry litter increases the protein content of soybean seeds by 135.80 % and 262.76 % compared to from T- and T+ respectively. Lipid content of seeds from 10 g of mycorrhizae +10 g of vivianite powder + 60 g of poultry litter plants were 1.25 times and 1.06 times higher than that of seeds from no treated plants and treated chemical fertilizer plants respectively. Seeds from treated plants with 10 g of mycorrhizae + 10 g of vivianite powder + 60 g of poultry litter were 2.17 and 1.40 times richer in total sugars compared to non-treated plants and chemical fertilizer plants respectively. The production and application of the mixture of 10 g of mycorrhizae + 10 g of vivianite powder + 60 g of poultry litter per plant at the sowing time for soybean growth would contribute not only to improve the nutritional values of this legume, but also valorize our local material in

organic farming, as well as to protect the environment.

Authors' contributions

Protocol writing and statistical analyses, C.M., LT.; Field work and laboratory analyses, F.K.K.; Drafted the manuscript, LTT.

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Availability of data and materials

All data will be made available on request according to the journal policy

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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