IMPACT OF A LOCAL ORGANIC FERTILIZER ON POTATO GROWTH AND PRODUCTION AND SOIL PROPERTIES

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ABSTRACT: A local liquid organic fertilizer named SolOrga Ghbar containing beneficial microorganisms and essential elements for plant nutrition was used to evaluate its effect on potato growth and production in field conditions, as well as on soil properties. Different doses of organic fertilizer i.e 0, 50, 100, and 200 L/ ha were used at 100% plant emergence and tuber formation stages, along with a commercial imported organic fertilizer as a control. A statistically significant improvement in plant growth kinetics and yield was observed following application of SolOrga Ghbar organic fertilizer at all studied doses. By applying SolOrga Ghbar organic fertilizer, potato production was almost double when compared to non-biofertilized plants and 30 % increase in production when compared to commercial organic fertilizer. SolOrga Ghbar application resulted in a significant increase in potato tuber size, suggesting an enhanced efficiency of soil mineral utilization. In addition, the application of SolOrga Ghbar at all concentrations reduced the soil pH and increases the percentage of organic matter in the soil. Application of the local organic fertilizer resulted in increased potato yield and improved soil properties, potentially enhancing nutrient availability and soil structure for subsequent horticultural crops.

KEYWORDS: Organic fertilizers, Compost extract, Potato crop, Soil organic matter, Tuber size.

INTRODUCTION

Modern agriculture system is based on the use of chemical fertilizers to increase crop production. Although, these chemicals have significant positive impact on crop production but their excess of use leads to the accumulation of harmful residues in Agrofood products such as nitrate and heavy metals. Current agricultural trends demonstrate a shift towards the adoption of organic products as alternatives to chemical fertilizers, aiming to ensure consumer and environmental safety. Valorization of crop residues through a composting process for the production of organic fertilizers is of great importance for economic as well as environmental purposes.

The use of compost in agriculture is a well-known practice to enrich the soil with nutrients, organic matter and beneficial microorganisms, which contributes to increase agriculture production and resistance of plants to soil-borne pathogens (Ozores-Hampton *et al.*, 2022; Neher *et al.*, 2022). Thus, the use of compost reduces the application of chemical fertilizers and improves the resilience of the agrosystems. In the last decade, the use of compost products such as compost extracts are easier to use through drip irrigation system and showed rapid and positive effects on plant growth and production (Samuelson *et al.*, 2019). The compost extract is obtained by mixing mature compost with water, and stirring this mixture for a set period of time, which may or may not be aerated. This extract serves as a natural fertilizer, comprising organic matter, minerals, and a particularly high concentration of beneficial fungal and bacterial microorganisms. Compost extracts are proposed as biological inocula that

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promote plant growth, increase soil microbial abundance and diversity, suppress diseases, accelerate residue decomposition and nutrient cycling, and can suppress weeds (El-Masry *et al.,* 2002; Zinati, 2018).

In Africa, generally the organic fertilizers sector is underdeveloped, and the situation varies across the countries. The organic fertilizers market was estimated to 45.076 million US dollars in 2017 in Africa and is expected to grow by 5.9% annually during the forecast period 2020-2025 (Anonymous, 2022). In Tunisia, several organic fertilizers are marketed; however, the majority of them are imported mainly from European countries which are not particularly adapted to Tunisian pedoclimatic conditions. So, several Tunisian companies are moving toward the development of local organic fertilizers. A new local liquid organic fertilizer of plant origin named SolOrga Ghbar rich in beneficial microorganisms and macro- and micronutrients for plants was developed by Poulina Group Holding. In order to validate the benefits of this compost extract at a commercial scale, the objectives of this work were to evaluate its effect on the growth and production of a staple crop in Tunisia i.e. potato, as well as some soil properties through an on-farm research study.

MATERIAL AND METHODS

Plant material and culture conditions

The Spunta variety of potato was used in this study, which covers 80 % of cultivated potato areas in Tunisia. The potato seeds were acquired from the inter-professional group of vegetables in Tunisia and pre-germinated before planting. The planting was done on January 26th, 2022 in a clay-silt texture soil in the Takelsa region in Northeastern region of Tunisia (Fig. 1). The pre-germinated potato seed were planted with a spacing of 30 cm between the plants on the row and 85 cm between the rows. The test plot was about 0.5 ha divided into two blocks each containing all the treatments (Fig. 1). The fertilization of the plants was made by conventional chemical fertilizers based on NPK fertilization program with 313 units of nitrogen (N), 328 units of phosphorus (P_2O_5) and 262 units of potassium (K_2O) per hectare. The irrigation of the plants was done by the drip system according to the needs of the plants. The uniformity of the irrigation system coefficient was about 80 %.

SolOrga Ghbar properties, application and treatments

The organic fertilizer SolOrga Ghbar is an extract of plant debris compost rich in bacterial (10^5 CFU/mL of beneficial *Bacillus* spp.) and fungal microorganisms with a bio-stimulating effect on plant growth. SolOrga Ghbar, with an acidic pH of 5.5, provides essential plant nutrition through a composition of macronutrients (nitrogen 0.15% w/w, phosphorus 0.007% w/w, potassium 0.32% w/w, calcium 0.01% w/w, magnesium 0.0052% w/w) and micronutrients (iron, copper, manganese, zinc, molybdenum, boron), alongside 0.7% w/w humic acid. For plant fertilization, the SolOrga Ghbar product was applied through the drip system at two

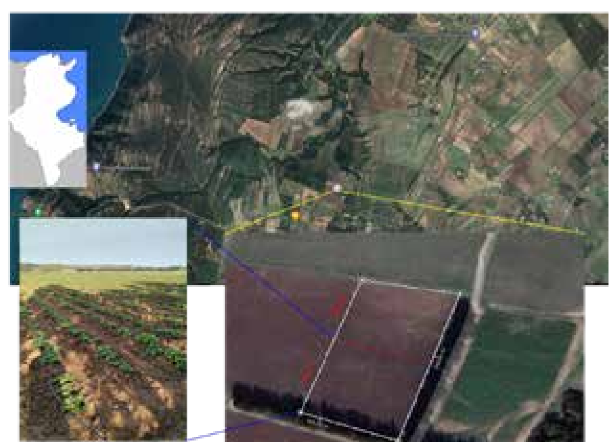

Fig. 1. Localization and experimental design of the essay of the organic fertilizer SolOrga Ghbar effect on potato crop in field conditions in the Takelsa region in Tunisia.

stages 100% emergence of potato plants and tuber formation. The SolOrga Ghbar product was applied at the doses of 50 L/ha (LDG50), 100 L/ha (LDG100) and 200 L/ha (LDG200). Plants receiving only the conventional chemical fertilization program without bio-fertilization were used as a control (LDG0). The imported liquid organic fertilizer of plant origin BioCAT15 containing 15 % w/w of humic-fulvic acids and 4.5 % w/w of potassium was used as a reference at 40 L/ha as recommended by the manufacturer.

Measured parameters on potato crop

Potato plant growth kinetics was monitored by measuring plant cover at three times corresponding to the initial state of potato culture (37 days after planting), 15 days after the first application (52 days after planting) and at tuber formation (67 days after planting) using the Canopeo application (Patrignani and Ochsner, 2015). The final production of the plants was estimated at 103 days after planting by uprooting the tubers from 4 rows of 48 m per treatment and per block. The total fresh weight, large size (Ø > 60mm), and small to medium size (35 mm > Ø >55 mm) tubers were measured at the final harvest using a commercial balance.

Soil parameters determination

The soil samples were taken from the upper 20 cm of the soil corresponding to the maximum root development area for potato plants. For the soil properties analyses of the pH, Electro-conductivity (µs/cm) and the percentage of organic matter were determined according to standard methods. For the determination of pH and electrical conductivity (EC), 200 g of dry and sifted soil were hydrated with distilled water gradually until a saturated paste was obtained. After 2 hours, the soil solution (extracted from the saturated paste) was recovered using a vacuum pump. The recovered solution was used to measure electrical conductivity using a conductivity meter and a pH meter. The determination of organic matter (OM) in agricultural soils was carried out by determining the organic carbon according to the Walkley-Black method which is based on the oxidation of organic carbon by potassium dichromate, $K_2Cr_2O_7$ (CAS: 7778-50-9) in a strongly acidic environment. 10 mL of the solution (1 N) of $K_2Cr_2O_7$ and 20 mL of concentrated sulfuric acid (96%) are added to 1 g of dry, sifted soil. Stir solution for 1 min and leave to rest for 30 min. Then add 200 mL of distilled water, 10 mL of orthophosphoric acid (85%), H_3PO_4 (CAS: 7664-38-2) and 1 mL of barium diphenylamine sulfonate indicator solution (0.10% W/V) (CAS: 6211-24-10). The titration is then carried out with the ferrous sulfate solution (0.5 N), $FeSO_4 \bullet 7H_2O$ (CAS: 7782-63-0) until the indicator turns green. The percentage of carbon is calculated by the following equation. Thus, the percentage of OM is given by the following equation.

Statistical analyses

All statistical analyses were performed using R x 64 3.5.1 software and Mixed Linear Models (MLM) was implemented for analyses of variance. All data were tested for normality using a Shapiro-Wilk's test to assess homogeneity of variance. Multiple mean comparisons were performed using Tukey HSD test at α = 0.05.

RESULTS

Effect of SolOrga Ghbar on potato growth kinetics

The analysis of variance showed a significant effect of the treatments with the organic fertilizers on the area under the curve of vegetative growth kinetics (AUDPC) (Table 1). The comparison of means by the Tukey test at α = 0.05 showed that the potato plants treated with SolOrga Ghbar at the different studied doses i.e. 50, 100 and 200 L/ha had significantly higher plant cover compared to plants without bio-fertilization and to those which received the organic fertilizer BioCAT15 (Fig. 2).

Effect of SolOrga Ghbar on potato production

Effect on total tuber production

The analysis of variance showed a significant effect of the treatments with the organic fertilizers on the total yield of the potato crop (Table 2). The comparison of the means showed that potato plants treated with SolOrga Ghbar using the three doses have significantly higher yields in comparison to non bio-fertilized plants and those which received the commercial product BioCAT15 (Fig. 3). Application of SolOrga Ghbar at 50 L/ha significantly increased potato tuber yield, achieving 43.28 t/ha, compared to 21.70 t/ha for the control. Yields of 42.81 t/ha and 46.41 t/ha were recorded for applications of 100 L/ha and 200 L/ha, respectively. BioCAT15 resulted in a yield of 33.02 t/ha (Fig. 3). Notably, SolOrga Ghbar exhibited no adverse effects on potato development throughout the growth cycle, even at the highest application rate (200 L/ha).

Table 1. Analysis of the variance of the area under the progression curve of potato plant cover. Potato plants were treated or not with different doses of a local (SolOrga Ghbar) and imported (BioCAT15) biofertilizers.

	Sum Sq	df	F value	Pr(>F)
Treatment	0.027352	4	2.5806	0.04213*

R significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 2. Analysis of variance of the total yield of potato crop. Potato plants were treated or not with different doses of a local (SolOrga Ghbar) and imported (BioCAT15) biofertilizers.

	Sum Sq	df	F value	Pr(>F)
treatment	1642.79	4	53.319	1.086e-08***

R significance codes 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Effect on the tuber size

The analysis of variance showed a significant effect of the treatments with

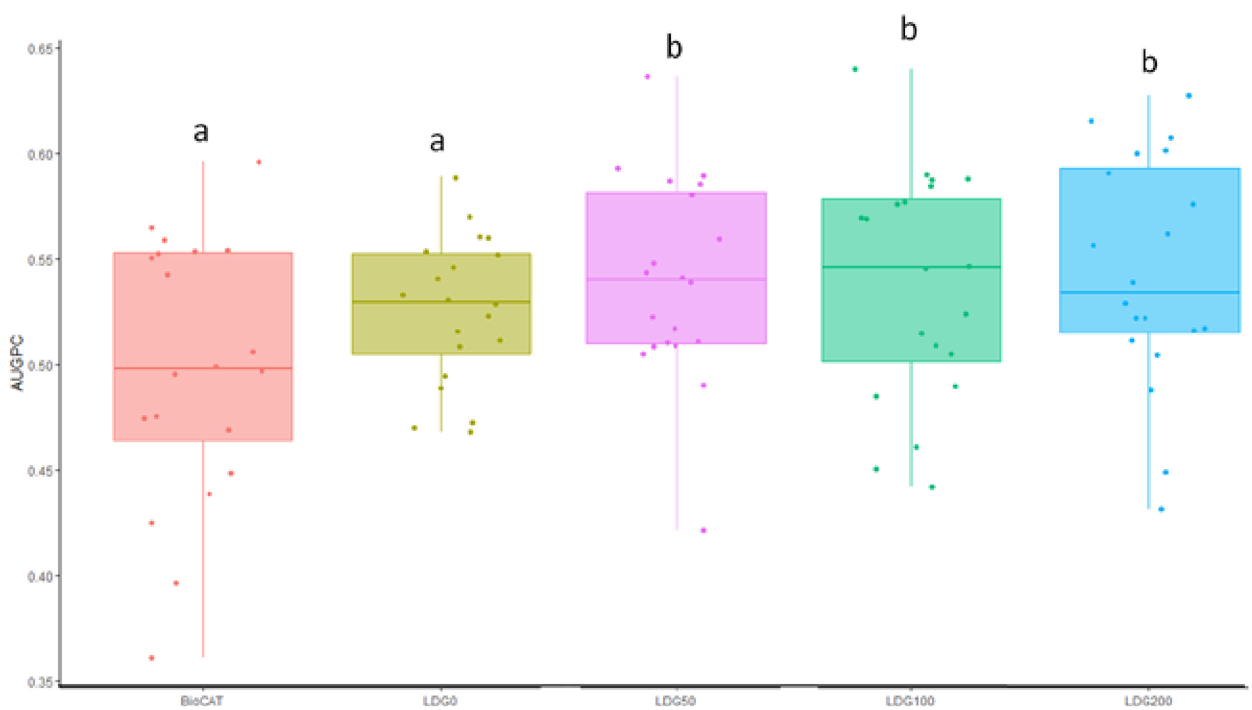

Fig. 2. Effect of the organic fertilizer SolOrga Ghbar on the area under the growth progression curve (AUGPC) of potato plants cv. Spunta.

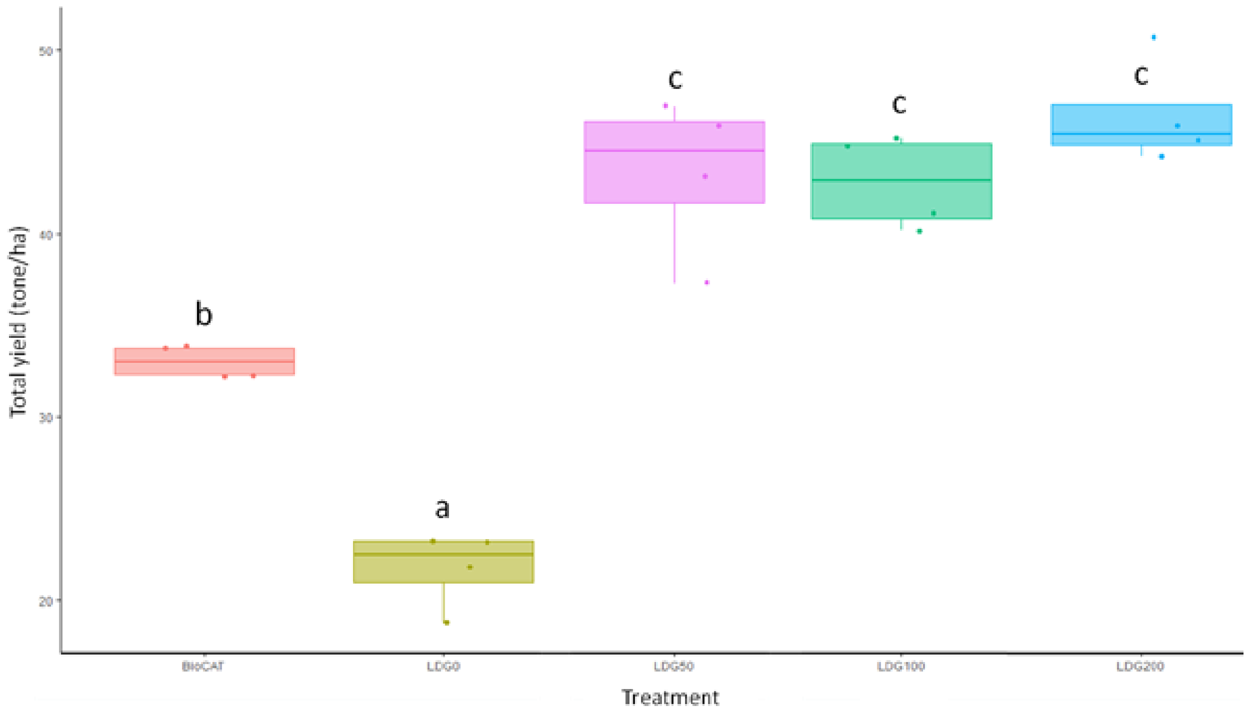

Fig. 3. Effect of the organic fertilizer SolOrga Ghbar on the total yield of potato plants cv. Spunta.

the organic fertilizers on the percentage of small-medium and large size tubers of potato crop (Table 3). The comparison of means showed that control potato plants produced significantly more small-medium size tubers in comparison to plants treated either by the local SolOrga Ghbar and the imported BioCAT15 organic fertilizers (Fig. 4). In general, the fertilization with SolOrga Ghbar and BioCAT15 organic fertilizers improved the percentage of large size tubers compared to the control plants (Fig. 5). Potato plants treated with SolOrga Ghbar at 100 L/ha and 200 L/ha exhibited the highest percentage of large-sized tubers compared to all other treatments (Fig. 5).

Effect of SolOrga Ghbar on soil properties

The results of the soil analysis after potato harvest showed that the two organic fertilizers used SolOrga Ghbar and BioCAT15 reduced the pH of the soil with the lowest values obtained for the treatments 100 L/ha and 200 L/ha of SolOrga Ghbar (Table 4). SolOrga Ghbar product at given doses also reduces EC of Soil when compared to control (Table 4). The analysis of the percentage of organic matter in the soils showed that the two organic fertilizers increased this parameter compared to the control with superiority for BioCAT15 which is a product

Table 3. Analysis of the variance of the percentage of small-medium and large size tubers in the potato crop. Potato plants were treated or not with different doses of a local (SolOrga Ghbar) and imported (BioCAT15) biofertilizers.

	Sum Sq	df	F value	Pr(>F)
Effect of treatment on the percentage of tubers of small to medium size	724.32	4	12.726	0.0001026***
Effect of treatment on the percentage of large size tubers	329.82	4	5.8016	0.005005**

R significance codes 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

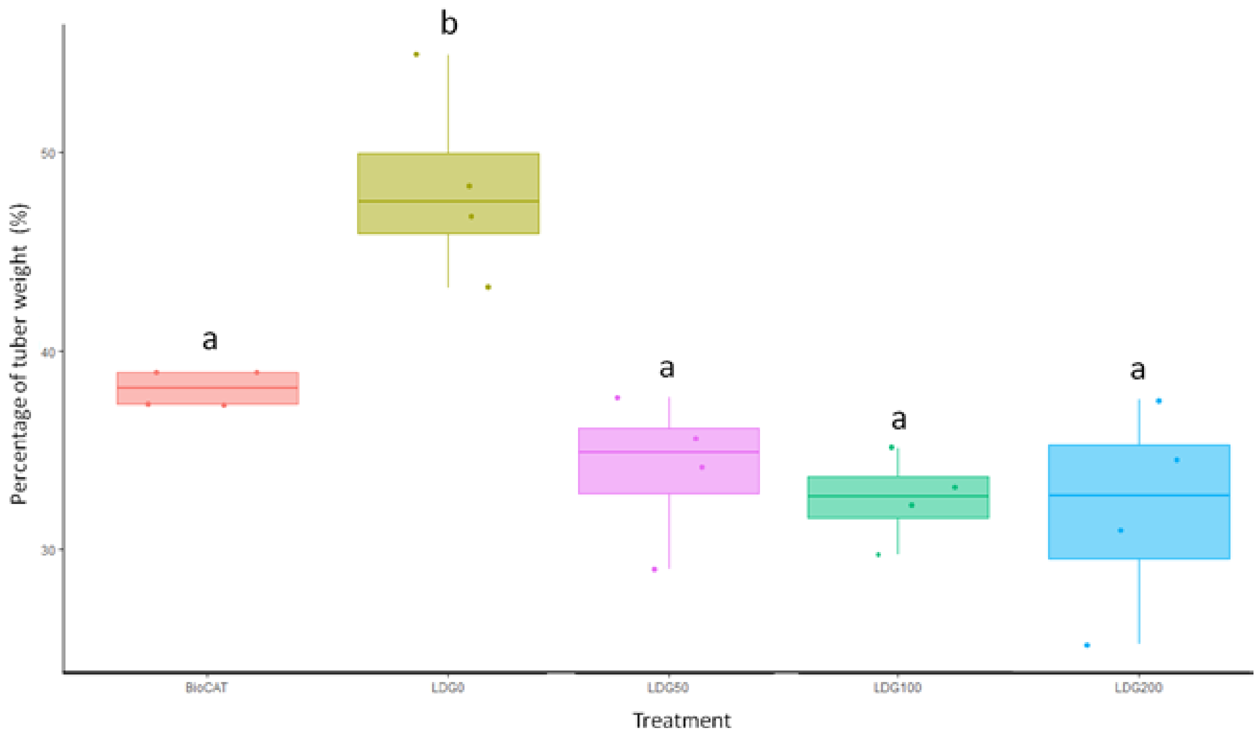

Figure 4. Effect of the organic fertilizer SolOrga Ghbar on the percentage of small-medium size tubers produced by potato plants cv. Spunta.

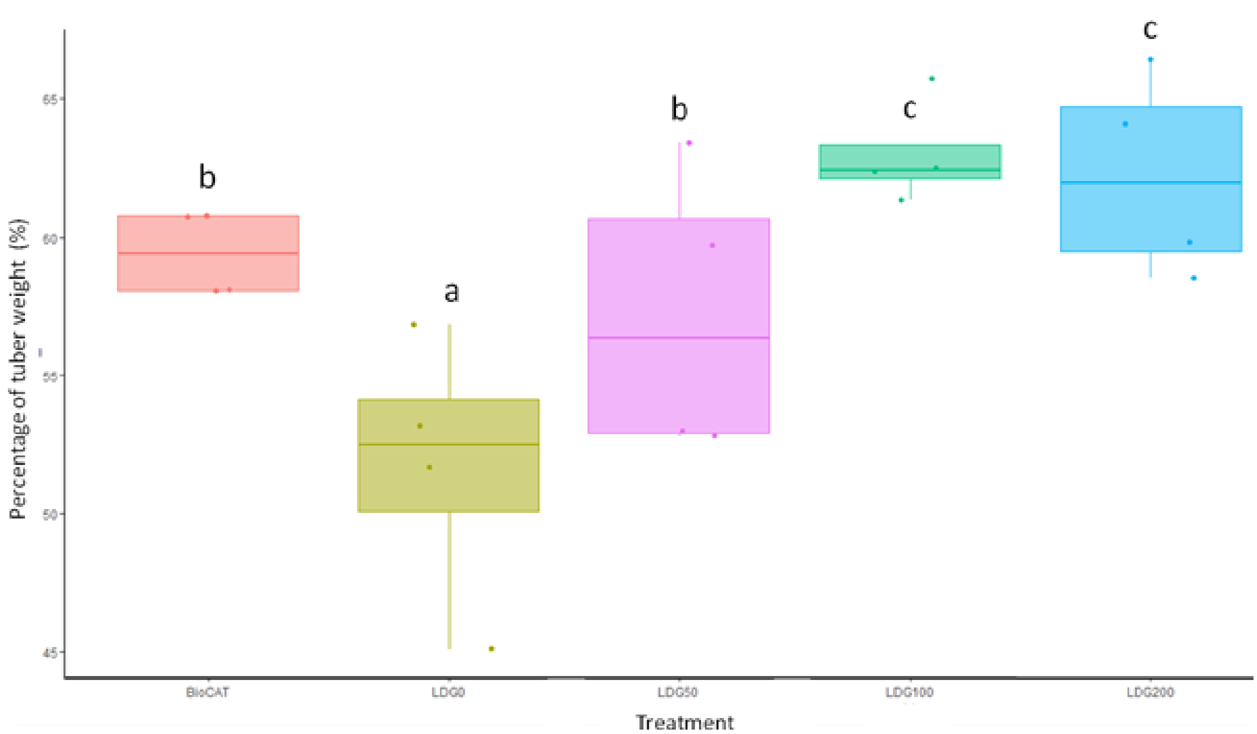

Figure 5. Effect of the organic fertilizer SolOrga Ghbar on the percentage of large size tubers produced by potato plants cv. Spunta.

Table 4. Effect of the SolOrga Ghbar biofertilizer on soil properties.

Treatment	Soil properties		
	pH	Electroconductivity (µs/cm)	Organic matter (%)
LDG0	8.26	79.2	3.80
LDG50	7.90	67.5*	5.20*
LDG100	7.60	59.7*	5.30*
LDG200	7.26	66.4*	7.80*
BioCAT15	7.99	78.7	8.70*

R significance codes 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

with high content (15%) in humic-fulvic acids (Table 4).

DISCUSSION

The intensive agricultural production system based on the exclusive use of chemical fertilizers is more than ever questioned because of its negative repercussions on human health, the environment, and the accentuation of climate change. For this reason most countries in the world claim to include agriculture in their potential climate change mitigation options. Thus, to adapt and improve its resilience, while reducing its impact on the climate, agriculture can rely on the principles of agro-ecology. The concept of agro-ecology is based on the optimization of biological regulation processes, the economical management of natural resources and the recycling of nutrients aimed at ensuring sustainable agricultural production, healthy and diversified nutrition. The agro-ecological transition of agriculture can be based on solutions of a technical nature which consist in mobilizing functional biodiversity to improve the performance of cropping systems. The use of organic fertilizers from which composts and their extracts fit within this scope, which make possible to reduce the use of chemical fertilizers and even naturally regulate the attacks of bio-aggressors reducing also the use of pesticides and thus reduces the risk of environmental pollution.

Fortunately, developed countries are moving toward the regulation of the use of chemical agro-products and encourage the production and use of biopesticides and organic fertilizers through the revision of their national policy. Generally, the organic fertilizer production sector is underdeveloped in Africa, and the situation varies across countries and regions, depending on the status of ecological organic agriculture policy, and government support (Willer *et al.,* 2022). In Tunisia the organic fertilizers are increasingly available in the market due to the development of the organic agriculture sector, but they are mainly imported from European countries. However, many research studies showed that indigenous microorganisms based organic fertilizers were more adapted to local pedoclimatic conditions in comparison to foreign products made from allochthonous microbial strains (Mhadhbi *et al.,* 2009; Ferchichi *et al.*, 2019; Ben Romdhane *et al.*, 2022). Thus, several research laboratories and private companies are moving toward the development of local organic fertilizers to ensure efficiency in the field to meet farmer's expectations. So, the objective of this study was to evaluate the performance of a novel liquid local organic fertilizer named SolOrga Ghbar developed by Poulina Company on the growth and production of potato, as well as on some soil properties.

This study showed that SolOrga Ghbar increased the growth of potato plants following its application at two stages of 100 % plant emergence and at tuber formation at the doses of 50, 100 and 200 L/ha. By applying this local organic fertilizer, the potato yield increased by 2-folds in comparison to the control and by 30 % in comparison to the imported organic fertilizers BioCAT15 used as a reference. This yield improvement was in part due to the increase of the percentage of large tubers produced by potato plants treated with

SolOrga Ghbar. This result shows that SolOrga Ghbar treated plants produced appropriate commercial tuber size when compared to non-biofertilized plants which indicate an increase in precocity of production when using this local organic fertilizer. This observed beneficial effect may be attributed to the product's high content of plant growth-promoting and biocontrol microorganisms, including bacteria (Bacillus spp.) and fungi (Ben Slimene *et al.*, 2012; Metoui-Ben Mahmoud *et al.,* 2020; Ayed *et al.,* 2021; Sharma *et al.,* 2022).

Soil pH, electroconductivity and organic matter contents influence crop growth and yield, because they determine nutrients availability for plants. The local organic fertilizer SolOrga Ghbar improves the quality of the soil by lowering the pH of the soil, reducing its conductivity and increasing its organic matter content. Indeed, soil pH affects nutrient solubility of nutrients and microbial activity in particular the activity of nitrogen fixing microbes, as well as a direct effect on root cells multiplication which determine plant growth and development (Marschner, 1986; Neina, 2019). The soil electroconductivity is correlated to its salinity level which directly influences crop growth and development. The soil organic matter consists of organism's debris at various stages of decomposition, as well as their synthesized substances which provide numerous benefits to soil physical and chemical properties determining soil functions and quality (Beare *et al.,* 1994).

CONCLUSION

In conclusion, this study demonstrated that SolOrga Ghbar, a local organic fertilizer, outperformed the imported BioCAT15 (at its recommended dose) in enhancing potato growth and yield when applied at 50 L/ha during 100% plant emergence and tuber formation stages. By applying SolOrga Ghbar the average yield registered was about 44 tones/ha, showing an increase by 2-folds and 30 % in comparison to the control and BioCAT15, respectively. The significant effect of SolOrga Ghbar on increasing tuber size supports the hypothesis of its beneficial effect on the precocity of production. In addition, soil analyses showed that SolOrga Ghbar decreases the pH, and electroconductivity and increased organic matter content which improves soil properties.

AUTHOR CONTRIBUTIONS:

BK and AS: conducted the experiments. ND analyzed the data. ND and BK: interpreted the results. ND: wrote and corrected the paper. ND, SRJ and RZ: supervised the work. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST

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

ETHICAL STATEMENT

This article does not contain any studies with human participants or animals performed by any of the authors.

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