EFFECTIVENESS OF BIOPREPARATIONS FOR GROWING SWEET POTATO AND JERUSALEM ARTICHOKE IN SUSTAINABLE AGRICULTURE

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Abstract
Biopreparations, including microbial inoculants and organo-mineral fertilisers, offer a sustainable approach to improving crop yield and quality. This study examined their effects on the sweet potato (*Ipomoea batatas*) and Jerusalem artichoke (*Helianthus tuberosus*) under agroecological conditions in Ukraine. The highest sweet potato yield (17.4 t ha^{-1} average over three years) was achieved through foliar application of Humifriend (1.5 L ha^{-1}) and Help-Rost (2 L ha^{-1}). For Jerusalem artichoke, the best result (32.6 t ha^{-1}) followed fertigation with Mykofriend (1 L ha^{-1}) and two foliar applications of Help-Rost (2 L ha^{-1}). Key quality traits assessed included dry matter, starch, total sugar, and vitamin C content. Significant increases in dry matter, total sugar, and vitamin C were recorded for both crops, with the strongest effects observed in total sugar for sweet potato and dry matter for Jerusalem artichoke. In contrast, starch content in Jerusalem artichoke showed no significant response. These results highlight the potential of Mykofriend and Help-Rost to enhance root crop productivity and nutritional value while reducing environmental impact. The findings support broader use of biopreparations in sustainable agriculture and emphasise the importance of optimising treatment strategies to maximise agronomic performance.
Keywords: microbial inoculants, organo-mineral fertilizers, tuber crops, sustainable fertilization, biofertilizers.

Introduction

The increasing demand for ecologically sound, resource-efficient, and climate-resilient agricultural systems has catalyzed a paradigm shift toward the use of biopreparations such as microbial inoculants, biofertilizers, and organo-mineral amendments as viable and sustainable alternatives to synthetic agrochemicals. These biologically active inputs enhance nutrient cycling, improve soil structure, increase plant resilience to abiotic stress, and support ecosystem services that are often degraded under intensive conventional practices (Bolokhovskyi et al., 2025). Their integration into agroecological systems is becoming a cornerstone of regenerative agriculture and long-term soil fertility strategies (Sofo et al., 2022).

Biopreparations function through complex biochemical and ecological interactions within the soil and plant continuum. Consortia of beneficial microorganisms including *Azotobacter*, *Bacillus* spp., mycorrhizal fungi, and *Pseudomonas fluorescens* can boost nutrient availability, suppress phytopathogens, and stimulate plant hormone pathways that enhance root growth and stress tolerance (Nakielska et al., 2024). When combined with organic amendments such as humic substances, amino acid complexes, or composted biomass, these inputs not only enrich microbial diversity but also restructure the soil matrix to improve aeration, moisture retention, and cation exchange capacity (Breza-Boruta & Bauza-Kaszewska, 2023). Furthermore, such biologically driven systems reduce the need for chemical fertilisers, which lowers environmental contamination risks and contributes to cleaner food production (Vasylovych, 2024; Romanowska-Duda et al., 2020).

These benefits are particularly significant for tuber crops such as Jerusalem artichoke (*Helianthus tuberosus*) and sweet potato (*Ipomoea batatas*), which serve as important sources of carbohydrates, fiber, antioxidants, and bioactive compounds. They are widely used not only in food systems but also in feed, energy, and pharmaceutical industries. Prior studies have demonstrated that bio-based inputs can substantially increase tuber yield and nutritional value, particularly in terms of dry matter, total sugars, starch, and vitamin C content, through enhanced nutrient uptake and plant metabolic efficiency (Ahmed & Alian, 2023; Antonious, 2024; Liu et al., 2024). In parallel, the valorization of sweet potato processing residues, especially peels, has attracted attention as a model for circular bioeconomy and industrial upcycling (Jiang et al., 2024).

The effectiveness of biopreparation-based fertilisation systems is closely linked to the physical properties of soil, including bulk density, porosity, moisture retention capacity, and aeration. These factors significantly influence microbial colonization and rhizosphere activity. Long-term tillage practices can alter the structure of bacterial communities and improve soil physicochemical characteristics. In particular, rotary and chisel tillage reduce compaction, increase organic matter content, and enhance phosphorus availability. These improvements create a favorable environment for beneficial microorganisms, stimulating their metabolic activity in the root zone. Maintaining a structured and biologically active topsoil is essential for sustaining stable microbe-plant interactions and ensuring the success of microbial inoculants under field conditions (Sun et al., 2023).

Recent research confirms the synergistic effects of combining reduced tillage with microbial and organic inputs. These integrative systems promote microbial biomass, elevate soil organic carbon levels, and improve nutrient availability, which collectively enhance yield and soil resilience (Kanarek et al., 2022). Field studies have also documented productivity and quality gains when microbial treatments are used alongside composts, humic substances, or digestates, particularly in low-input and organic farming systems (Williams et al., 2020; Yang et al., 2022).

Despite these promising advances, field-level data on the combined use of microbial biopreparations and organo-mineral fertilisers under Ukrainian agroecological conditions remain scarce, especially for underutilized yet high-potential crops like the sweet potato and Jerusalem artichoke. Preliminary findings suggest that products such as Mykofriend, Help-Rost, and Humifriend can improve not only yields but also key biochemical parameters. However, their consistent performance across diverse environments and crop phenophases requires further validation.

This study aims to evaluate the agronomic performance of selected microbial and humic biopreparations on *Ipomoea batatas* and *Helianthus tuberosus* grown in steppe soils of eastern Ukraine. The goal is to develop practical recommendations for sustainable fertilisation systems that enhance productivity, nutrient use efficiency, and product quality while minimizing environmental impact.

Materials and Methods

Field experiments were carried out from 2021 to 2024 at the Donetsk Experimental Station of the Institute of Vegetable and Melon Growing, NAAS of Ukraine, to assess the effects of selected biopreparations on the yield and biochemical quality of *Ipomoea batatas* and *Helianthus tuberosus*. The site is located on typical chernozem soils with 4.3% humus, hydrolysable nitrogen at 139 mg kg^{-1}, available phosphorus ranging from 106 to 119 mg kg^{-1}, and exchangeable potassium at 93 mg kg^{-1}. The soil had a slightly acidic reaction (pH 5.7 in KCl), hydrolytic acidity of 2.8 mEq per 100 g, and base saturation of 26.0 mEq per 100 g. These properties reflect a moderately fertile matrix responsive to microbial and humic amendments, especially under steppe climate stressors (Breza-Boruta & Bauza-Kaszewska, 2023; Vasylovych, 2024).

A randomized complete block design (RCBD) with three replications per treatment was used. Each plot measured 33.6 m², with a central accounting area of 21 m² for data collection. Soil preparation included deep rotary tillage and strip loosening (25–30 cm) using a method adapted to improve seedbed aeration, reduce compaction, and ensure uniform seeding conditions under field environments. The selection of tillage depth and type was based on regionally tested practices that demonstrated improved water retention and reduced soil density under traditional and chisel tillage systems (Syromyatnikov et al., 2023, 2024). Five treatment variants were applied to the sweet potato cultivar 'Slobozhansky Ruby'. The control (Ctrl) received manure (20 t ha^{-1}) and wood ash (1 t ha^{-1}). The Ctrl+MF treatment added Mykofriend at 1 L ha^{-1} via fertigation. Ctrl+HR included two foliar applications of Help-Rost at 2 L ha^{-1}. Ctrl+MF+HR combined both Mykofriend and Help-Rost at the same doses. Finally, Ctrl+Hum+HR integrated Humifriend (1.5 L ha^{-1}) and Help-Rost (2 L ha^{-1}). Slips were planted in a (100+40) × 25 cm layout, reaching 58,000 plants ha^{-1}. Drip irrigation and black polyethylene mulch (120 μm) were used throughout the season to conserve moisture and control weeds, aligning with conservation agriculture principles (Romanowska-Duda et al., 2023).

A parallel treatment scheme was used for Jerusalem artichoke cultivar 'Dietetic'. The unfertilized control (Ctrl) was compared to four biopreparation variants. In Ctrl+MF, tubers were soaked in Mykofriend (2 L t^{-1}) before planting. Ctrl+MF+Fert involved additional fertigation with Mykofriend (1 L ha^{-1}) during early vegetative growth. Ctrl+HR included three foliar sprays of Help-Rost (2 L ha^{-1}) at key growth stages: 5–6 leaves, and 25 and 35 days after. The combined Ctrl+MF+HR treatment used both tuber inoculation and foliar Help-Rost. Jerusalem artichoke was planted at 29,000 plants ha^{-1} using a 70 × 50 cm spacing. Soil pre-treatment followed the same tillage strategy as for sweet potato.

The biopreparations tested included Mykofriend, Humifriend, and Help-Rost. Mykofriend is a complex microbial inoculant containing *Glomus* spp., *Trichoderma harzianum*, and rhizobacteria (*Bacillus subtilis*, *B. megaterium*, *Paenibacillus polymyxa*, *Pseudomonas fluorescens*) at 1.0–1.5 × 10^{9} CFU mL^{-1}. Humifriend is a humic-based biostimulant enriched with fulvic acids, amino acids, micronutrients, and microbial metabolites. Help-Rost is a foliar organo-mineral fertilizer containing essential nutrients, phytohormones, and growth regulators, suitable for organic farming (Nakielska et al., 2024).

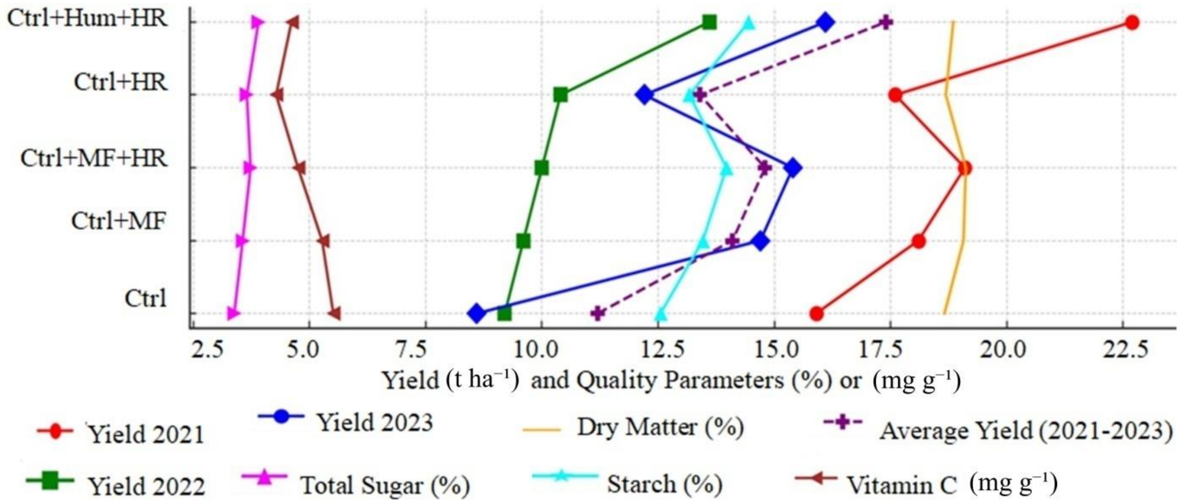
Harvested tubers were evaluated annually for marketable yield (t ha^{-1}). Biochemical analyses were conducted on 1.5 kg composite samples per treatment. Dry matter was determined by oven drying at 105 °C to constant weight (AOAC 930.15). Starch was assessed enzymatically (AOAC 996.11), total sugars by Luff–Schoorl titration (AOAC 923.09), and vitamin C using 2,6-dichlorophenolindophenol titration (AOAC 967.21). All measurements were performed in triplicate. Statistical analysis involved one-way ANOVA using R software (v4.3.1). Normality and homogeneity of variances were checked via Shapiro–Wilk and Levene's tests. Tukey's HSD test ($p < 0.05$) was used for post hoc comparisons among treatments.

Results and Discussion

The effect of various fertilisation systems on the yield and quality of *Ipomoea batatas* was evaluated over the three-year period from 2021 to 2023. As shown in Figure 1, the average yield in the control treatment (Ctrl), which included only manure (20 t ha^{-1}) and ash (1 t ha^{-1}), was 11.2 t ha^{-1}. The lowest yield in this group was recorded in 2023 (8.6 t ha^{-1}), whereas the highest was observed in 2021 (15.9 t ha^{-1}). The treatment Ctrl+Hum+HR, which combined Humifriend (1.5 L ha^{-1}) and Help-Rost (2 L ha^{-1}), resulted in the highest average yield of 17.4 t ha⁻¹, with respective annual values of 22.7, 13.6, and 16.1 t ha⁻¹. Other biopreparation-based treatments also demonstrated notable improvements in productivity, with Ctrl+MF+HR and Ctrl+Help consistently outperforming the control.

Figure 1

Sweet potato yield and quality indicators under different fertilisation treatments (2021–2023) Lines represent the same treatment across years and do not imply sequential dependence

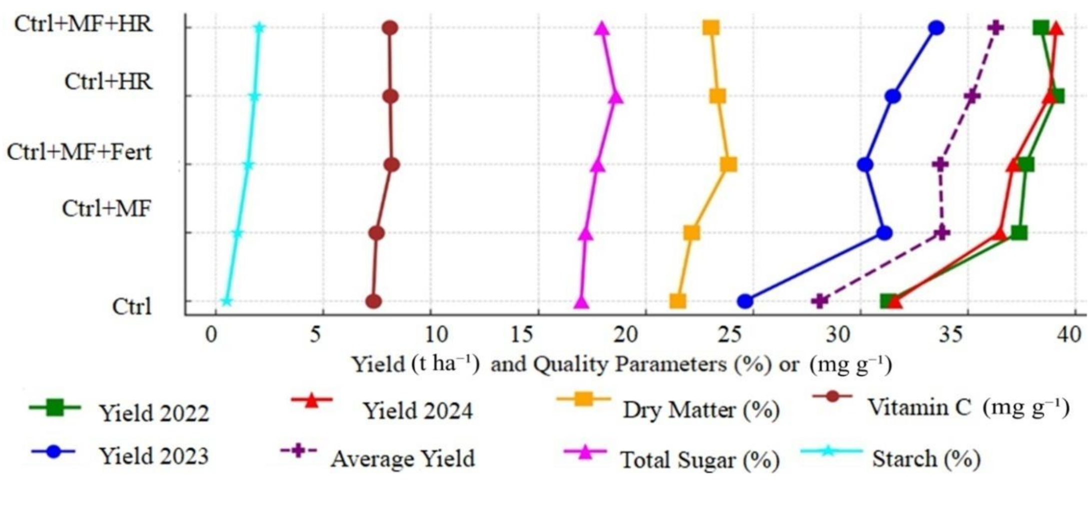


The analysis of tuber quality in sweet potato indicated that biopreparations positively influenced several key parameters. The highest dry matter content (19.12%) was recorded in the Ctrl+MF+HR treatment, whereas the highest starch content (14.45%) and total sugar content (3.90%) were observed in the Ctrl+Hum+HR variant. The vitamin C content was highest in the control treatment (5.51×10^{-2} mg g⁻¹) and lowest in the Ctrl+MF+HR treatment (4.75×10^{-2} mg g⁻¹).

The effects of the treatments on the yield and quality of *Helianthus tuberosus* from 2022 to 2024 are presented in Figure 2. In the unfertilised control, the average yield was 26.2 t ha⁻¹, increasing from 22.3 t ha⁻¹ in 2022 to 31.6 t ha⁻¹ in 2024. Application of Mykofriend (2 L t⁻¹) for tuber treatment (Ctrl+MF) resulted in an average yield of 31.5 t ha⁻¹, while Mykofriend fertigation (Ctrl+MF+Fert) produced 31.3 t ha⁻¹. The highest average yield (32.6 t ha⁻¹) was obtained with the combined application of Mykofriend and Help-Rost (Ctrl+MF+HR), which yielded 27.6, 31.5 and 38.8 t ha⁻¹ in the respective years.

Figure 2

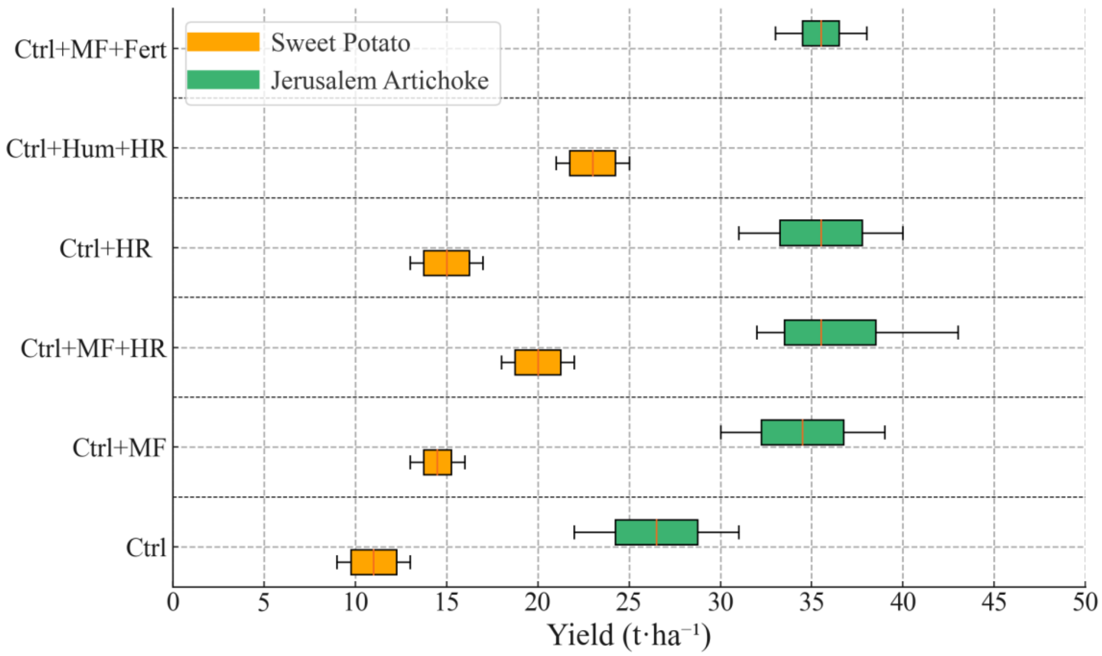
Jerusalem artichoke yield and quality indicators under different treatments (2022–2024) Lines connect values of the same parameter across independent treatments for visual clarity only



Quality analysis in Jerusalem artichoke demonstrated increases in dry matter, total sugar, and vitamin C levels following treatment. The control group exhibited a stable dry matter content of approximately

22.2%, whereas the Ctrl+MF+HR treatment raised this parameter to an average of 22.9%. Similarly, total sugar content increased from 17.3% in the control to 18.3% in Ctrl+MF+HR. The concentration of vitamin C, expressed in mg g^{-1}, rose from 7.53×10^{-2} in the control to 8.12×10^{-2} in the Ctrl+MF+Fert treatment.
Statistical analysis confirmed that the differences in yield between treatments were significant for both crops (the sweet potato exhibited a P-Value = 0.000004, whereas Jerusalem artichoke showed a P-Value = 0.027). The distribution of yield values by treatment is depicted in Figure 3. For the sweet potato, the highest median yield (22 t ha^{-1}) was obtained under the Ctrl+Hum+HR treatment, whereas Ctrl+MF+HR yielded 19 t ha^{-1}. The control treatment exhibited the lowest median yield at 16 t ha^{-1}. In the case of Jerusalem artichoke, the highest median yield (40 t ha^{-1}) was recorded for Ctrl+MF+HR, while the control showed the lowest value (27.5 t ha^{-1}). Broader interquartile ranges were observed in the treated groups compared to the controls, particularly for Jerusalem artichoke.

Figure 3
Yield Distribution of Sweet Potato and Jerusalem Artichoke Across Different Treatments



Quality parameters were also significantly influenced by the biopreparation treatments. The ANOVA results indicate strong statistical significance ($p < 0.001$) for dry matter, total sugar, and vitamin C content in both crops. Starch content was significantly affected only in the sweet potato, whereas in Jerusalem artichoke the differences were not statistically significant ($p = 0.332$). The detailed analysis of sweet potato quality is illustrated in Figure 4. Dry matter content increased from a median of 22% in the control to 24.5% in the Ctrl+Hum+HR treatment. Starch content also rose from 16% in the control to 17.2% under the same treatment. Total sugar content peaked at 4.9% in Ctrl+Hum+HR, compared to 4.5% in the control. Vitamin C content slightly decreased in the treated plots, with the control maintaining the highest median value (6.0×10^{-2} mg g^{-1}).
For Jerusalem artichoke, the distribution of quality parameters is presented in Figure 5. Dry matter content increased from 19% in the control to 21.5% in the Ctrl+Hum+HR treatment, while starch content remained low across all treatments. The highest total sugar content (4.3%) and vitamin C concentration (5.4×10^{-2} mg g^{-1}) were observed in Ctrl+Hum+HR. Although the vitamin C content was generally lower in the treated groups than in the control (5.5×10^{-2} mg g^{-1}), the differences observed remained within the range of acceptable biological variability.
The application of biopreparations significantly improved the yield and quality of both *Ipomoea batatas* and *Helianthus tuberosus* under Ukrainian agroecological conditions. Among all variants, combined treatments particularly Ctrl+Hum+HR and Ctrl+MF+HR consistently delivered superior outcomes. The sweet potato yield increased from 11.2 t ha^{-1} in the control to 17.4 t ha^{-1} in Ctrl+Hum+HR, while Jerusalem artichoke yield rose from 26.2 t ha^{-1} to 32.6 t ha^{-1} under Ctrl+MF+HR. These results correspond with findings by (Antonious, 2024), who reported enhanced sweet potato productivity and nutritional quality following applications of biochar and organic fertilizers an effect attributed to improved nutrient availability, soil structure, and microbial activity.

Dry matter and total sugar content also increased significantly under the biopreparation treatments, supporting their role in promoting carbohydrate accumulation. The treatments Ctrl+Hum+HR and Ctrl+MF+HR showed the highest gains in both parameters. These effects align with the findings of (Ahmed & Alian, 2023), who reported that Jerusalem artichoke harvested later in the season accumulated more sugars and inulin. This may reflect improved root function and extended vegetative growth stimulated by microbial and humic amendments.

Figure 4

Impact of Biopreparations on Key Quality Attributes of Sweet Potato

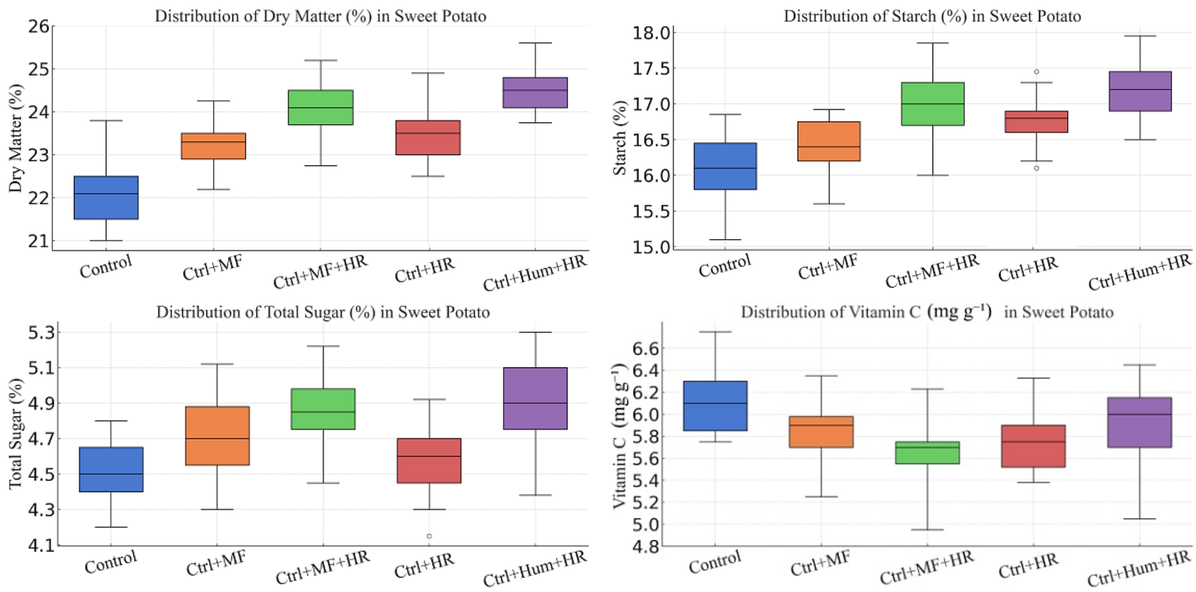
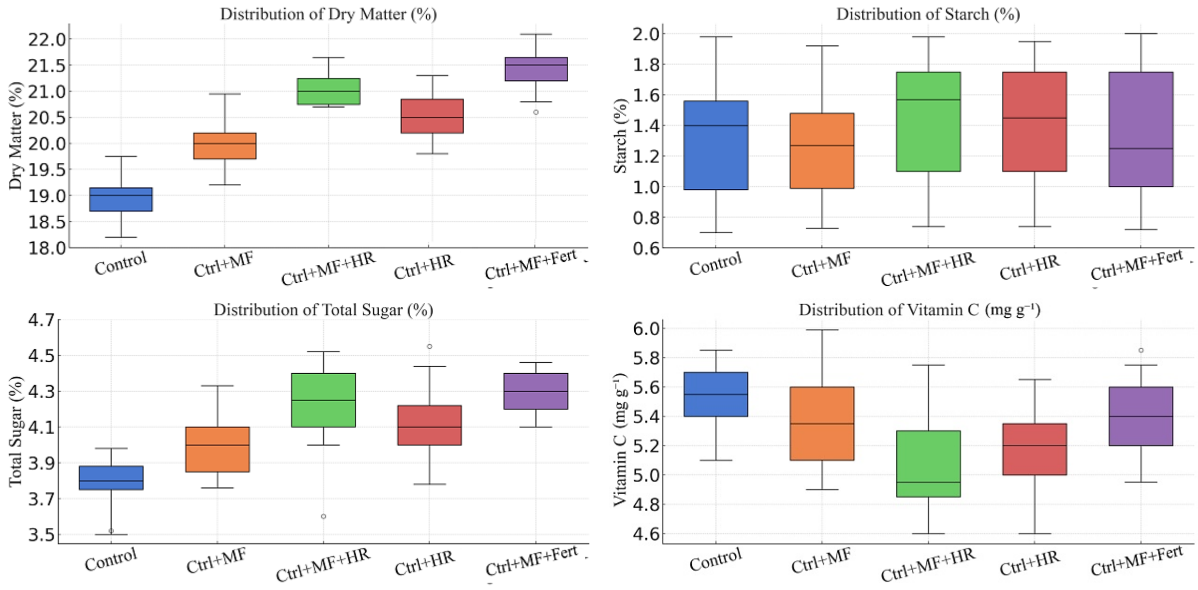


Figure 5

Effect of Biopreparations on Key Quality Parameters of Jerusalem Artichoke



Vitamin C trends varied between crops. In the sweet potato, the control retained the highest ascorbic acid content, while biopreparation-treated plots showed a modest decline. This may indicate a physiological shift towards increased carbohydrate biosynthesis at the expense of antioxidant accumulation, as also observed by (Antonious, 2024). In contrast, Jerusalem artichoke vitamin C content improved in the Ctrl+MF+Fert and Ctrl+MF+HR treatments, suggesting that foliar nutrient application may alleviate oxidative stress and promote antioxidant metabolism consistent with outcomes seen in organically grown root crops (Romanowska-Duda et al., 2020). Statistical analysis confirmed strong treatment effects ($p < 0.05$) on yield, dry matter, total sugar, and vitamin C content, highlighting the synergistic potential of microbial inoculants and humic stimulants. The role of Mykofriend containing arbuscular mycorrhizal fungi, *Trichoderma harzianum*, and beneficial rhizobacteria in supporting root growth and nutrient uptake appears central to these results, especially when combined with Humifriend and Help-Rost (Breza-Boruta & Bauza-Kaszewska, 2023; Nakielska et al., 2024).

These synergistic effects are echoed in the work of (Romanowska-Duda et al., 2023), who demonstrated that integrating digestate and ash with biopreparations enhanced yield and physiological performance in sorghum. A similar mechanism may explain the high performance of Jerusalem artichoke in our Ctrl+MF+HR variant, where repeated foliar sprays sustained metabolic activity during tuber formation. The pathogen-suppressive and stress-mitigating properties of microbial consortia, as shown in strawberries (Nakielska et al., 2024), may also explain the improved stability and quality observed in treated plots. Starch content in Jerusalem artichoke remained statistically unchanged across treatments ($p > 0.05$), in line with earlier findings by Yang et al., 2022, who indicated that starch and inulin profiles are more sensitive to harvest timing and environmental factors than to fertilizer treatments. Our data reflects this, showing increases in sugar content without proportional gains in starch. Yield variability observed in Figure 3 indicates that Jerusalem artichoke responded more strongly to environmental modifications induced by biopreparations than the sweet potato. This may be due to the greater adaptive plasticity of *H. tuberosus*, as suggested by Anwar et al. (2020), who reported that compost application and canopy management significantly influenced yield and biochemical composition.

While our findings confirm the agronomic benefits of microbial and humic formulations, they also highlight areas for further research. The physiological basis for the observed reduction in vitamin C in sweet potato remains unclear and warrants investigation. Future work may employ chlorophyll fluorescence techniques as proposed by (Pszczółkowski et al., 2023) to non-invasively monitor photosynthetic performance and clarify plant responses to biopreparation treatments under field conditions.

Conclusions

1. The integrated application of biopreparations enhances crop yield and quality. The combined use of microbial inoculants (Mykofriend, Help-Rost) and humic substances (Humifriend) significantly improved the yield and nutritional quality of sweet potato (*Ipomoea batatas*) and Jerusalem artichoke (*Helianthus tuberosus*). Treatments such as Ctrl+Hum+HR and Ctrl+MF+HR demonstrated the highest efficacy, particularly in increasing dry matter, starch, and total sugar content. While vitamin C levels slightly declined in the sweet potato, they were maintained or increased in Jerusalem artichoke under fertigation regimes.
2. Statistical validation confirms the effectiveness of biological treatments. The observed differences in agronomic and quality parameters were statistically significant, supporting the efficacy of biopreparation-based fertilisation strategies. These treatments offer a sustainable alternative to conventional fertilisers, reducing dependence on synthetic agrochemicals while maintaining high productivity and crop value.
3. Future optimisation should focus on physiological mechanisms and monitoring tools. Further studies should explore the underlying physiological basis for changes in antioxidant content and assess the utility of chlorophyll fluorescence as a non-invasive tool for monitoring plant responses. The findings support broader adoption of biopreparation-based technologies in organic and low-input farming systems to improve soil health, enhance crop performance, and promote sustainable agricultural development.

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