ASSESSMENT OF DAYMSA NATURAL CYTOKININS ON AGRONOMIC AND PHYSIOLOGICAL TRAITS OF SOLANACEOUS CROPS: EVIDENCE FROM GRAFTED EGGPLANT

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RESEARCH ARTICLE

Abstract
The increasing demand for sustainable horticultural production systems has stimulated interest in innovative technologies capable of enhancing crop performance while reducing dependence on intensive chemical inputs. Among these approaches, biostimulants containing natural cytokinins have received considerable attention due to their role in regulating physiological processes, improving nutrient utilization, and supporting plant productivity. The present study investigated the agronomic, physiological, and biochemical responses of grafted eggplant (Solanum melongena L.) cultivated under different fertilization regimes within a crop management system supported by Cytoplant 400 (DAYMSA, Spain), a natural cytokinin-based biostimulant. The experiment was conducted in Iași, Romania, using a split-plot design with three replications. Two commercial cultivars (Mirval F1 and Black Pearl F1), three grafting variants (non-grafted, grafted onto Rezistar F1, and grafted onto Solanum sisymbriifolium), and four fertilization regimes (control, Micoseed, organic, and chemical) were evaluated. Agronomic parameters related to productivity, physiological indicators associated with photosynthetic activity, and biochemical traits including antioxidant activity, total polyphenol content, tannins, and chlorophyll concentration were assessed. The results revealed significant interactions among cultivar, rootstock, and fertilization regime. The combination Mirval F1 × Rezistar F1 × Micoseed recorded the highest productivity, exceeding 112 t ha^{-1} and producing an average of 6.2 fruits per plant. Grafted plants showed superior physiological performance, particularly regarding photosynthetic assimilation and stomatal conductance. In addition, grafting combined with biological fertilization enhanced antioxidant activity and promoted the accumulation of bioactive compounds. Overall, the findings demonstrate that integrating grafting technology, targeted fertilization strategies, and cytokinin-supported crop management can simultaneously improve yield, physiological efficiency, and fruit quality, providing valuable insights for the development of sustainable eggplant production systems under protected cultivation conditions.

Keywords: Solanum melongena, grafting, Cytoplant 400, DAYMSA, natural cytokinins, biostimulants
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INTRODUCTION

Eggplant (Solanum melongena L.) is among the most widely cultivated vegetable crops worldwide and plays an important role in protected horticultural systems. As a member of the Solanaceae family, it is grown extensively throughout Asia and the Mediterranean region, while its cultivation has expanded considerably in Central and Eastern Europe during the last decades (Daunay *et*. Janick, 2007; Taher et al., 2017). This expansion is largely associated with its economic importance, nutritional value, and its ability to adapt to a wide range of growing conditions (Kaushik et al., 2021). At the same time, consumers are becoming increasingly interested in vegetables that provide not only basic nutrition but also compounds with potential health-promoting effects.

From a nutritional perspective, eggplant fruits contain a diverse range of bioactive substances, including phenolic compounds, flavonoids, anthocyanins, vitamins, minerals, and dietary fiber (Niño-Medina et al., 2017; Sharma et Kaushik, 2021). Several studies have highlighted the antioxidant properties of eggplant, which are mainly attributed to chlorogenic acid and other phenolic constituents. These compounds are known to contribute to the neutralization of free radicals and may have beneficial effects against inflammation-related disorders. For this reason, research in vegetable production is no longer focused exclusively on yield improvement, but also on enhancing the nutritional and functional quality of harvested fruits (Niño-Medina et al., 2017; Sharma et Kaushik, 2021).

Despite the progress achieved in intensive vegetable production, several challenges still remains. High fertilizer inputs, degradation of soil resources, and the increasing occurrence of biotic and abiotic stresses have raised concerns regarding the long-term sustainability of current production systems. In response to these issues, considerable attention has been directed toward cultivation strategies capable of maintaining high productivity while reducing environmental pressure. Among the most promising approaches are grafting technologies, biological fertilization, and the use of plant biostimulants (Rouphael *et.* Colla, 2020).

Grafting has evolved from a technique primarily used for the control of soil-borne pathogens into a multifunctional tool for improving crop performance. Numerous studies reported that grafted plants often exhibit greater vigor, enhanced nutrient uptake, improved tolerance to salinity and drought, and better adaptation to unfavorable environmental conditions. As a result, grafting has become increasingly common in the cultivation of Solanaceous crops, particularly under protected growing conditions (Lee et al., 2010).

The success of grafting, however, depends largely on the compatibility between scion and rootstock. Rootstocks can influence water and nutrient uptake, photosynthetic activity, biomass production, and even the accumulation of secondary metabolites. In eggplant cultivation, commercial rootstocks such as Rezistar F1, together with wild relatives like Solanum sisymbriifolium, have shown promising results in improving plant performance and stress resilience (Kyriacou et al., 2017).

Alongside grafting, plant biostimulants have emerged as an important component of sustainable crop management. Unlike conventional fertilizers, these products do not act primarily by supplying nutrients. Instead, they stimulate physiological and biochemical processes that improve nutrient use efficiency, stress tolerance, and crop quality. Among the different categories of biostimulants, products containing natural cytokinins have attracted particular interest due to their involvement in cell division, chloroplast development, photosynthetic activity, nutrient mobilization, and delayed leaf senescence (du Jardin, 2015).

Cytokinins are naturally occurring phytohormones that regulate a wide range of developmental processes. Their effects extend from shoot formation and leaf expansion to the regulation of photosynthesis and secondary metabolism. Previous research have demonstrated that cytokinin-based products may enhance chlorophyll content, improve antioxidant defense mechanisms, and support higher productivity under both favorable and stressful environmental conditions (Kieber et Schaller, 2018).

One such product is Cytoplant 400 (DAYMSA, Spain), a biostimulant formulated from plant-derived compounds rich in natural cytokinins. The product is designed to stimulate physiological activity, support vegetative development, and improve crop performance throughout the growing cycle (Rouphael et Colla, 2020).

Although the positive effects of biostimulants have been documented in several horticultural species, information regarding their integration within grafted eggplant production systems is still relatively limited (Yakhin et al., 2017).

Crop performance is rarely determined by a single factor. Instead, it results from the interaction between genotype, rootstock characteristics, nutrient availability, environmental conditions, and physiological regulation. Evaluating these factors separately often provides only a partial picture of plant behavior. Therefore, integrated studies that simultaneously investigate agronomic, physiological, and biochemical responses are becoming increasingly necessary (Kyriacou et al., 2017).

Most previous studies have examined yield, photosynthesis, or fruit quality independently. Comparatively fewer investigations have explored how grafting, fertilization strategies, and cytokinin-supported crop management interact to influence all of these components at the same time. This gap is particularly relevant for eggplant cultivated under protected conditions, where productivity, fruit quality, and sustainability must be balanced carefully (Rouphael et Colla, 2020).

The working hypothesis of the present research was that the integration of grafting technology, targeted fertilization strategies, and crop management supported by natural cytokinins could generate synergistic responses exceeding those obtained through individual technological interventions. It was expected that specific combinations of hybrid, rootstock, and fertilization regime would significantly affect productivity, physiological performance, and the accumulation of bioactive compounds in eggplant fruits.

Therefore, the main objective of this study was to evaluate the agronomic, physiological, and biochemical responses of grafted eggplant cultivated under different fertilization regimes within a production system supported by Cytoplant 400 (DAYMSA, Spain).

More specifically, the study aimed to assess the influence of hybrid, rootstock, and fertilization regime on productivity-related traits; determine the effects of technological combinations on photosynthetic performance and plant physiological activity; evaluate changes in antioxidant activity and bioactive compound accumulation in fruits; identify the most efficient technological combination for maximizing yield and fruit quality; and provide practical recommendations for sustainable eggplant cultivation under protected environments.

By bringing together agronomic, physiological, and biochemical evaluations within a single experimental framework, this research contributes new insights into the optimization of grafted eggplant cultivation and provides useful information for the development of more sustainable horticultural production systems.

MATERIAL AND METHOD

Experimental Conditions, Plant Material and Experimental Setup

The research was carried out over three consecutive growing seasons (2020–2022) at the University of Life Sciences in Iași, Romania. The trials were established under protected cultivation conditions similar to those commonly used by commercial vegetable growers in the region. The soil at the experimental site was a fertile chernozem with good physical properties for vegetable production, and all plots were maintained under comparable environmental and management conditions throughout the study.

Two eggplant (Solanum melongena L.) cultivars were selected because of their contrasting growth habits and production potential. Mirval F1 is an extra-early hybrid known for its vigorous growth and large fruits, while Black Pearl F1 is a semi-early cultivar characterized by stable production and good adaptability (Gautier Semences, 2022; Pop Vriend Seeds, 2022). Their main morpho-agronomic characteristics are presented in Table 1.

The experiment followed a factorial arrangement based on three factors that were expected to influence crop performance. The first factor was cultivar (Mirval F1 and Black Pearl F1), the second was rootstock (non-grafted plants, Rezistar F1, and Solanum sisymbriifolium), and the third was fertilization regime (control, Micoseed, organic fertilization, and chemical fertilization). The treatments were arranged in a split-plot design with three replications, resulting in 72 experimental plots distributed on approximately 256 m².

Table 1

Morpho-agronomic characteristics of the cultivars used in the experiment

Characteristic	Mirval F1	Black Pearl F1
Type of cultivation	Extra-early hybrid	Semi-early cultivar
Vegetation period	65–70 days	75–85 days
Plant habit	Vigorous, well-aerated	Medium vigorous
Internodes	Short	Medium
Resistance to high temperatures	Very good	Good
Fruit shape	Semi-long	Oval-short
Average fruit weight (g)	400–450	250–300
Fruit color	Intense glossy violet	Dark violet
Flesh consistency	Firm	Fleshy and juicy
Calyx characteristics	Slightly spiny	Soft, non-spiny
Recommended use	Protected cultivation, fresh market	Fresh market and household consumption

The two cultivars selected for the experiment represented distinct growth and production profiles, making them suitable for evaluating the interaction between genotype, grafting, and fertilization. Although both are widely used in protected cultivation, noticeable differences can be observed in their vegetative characteristics and fruit traits.

Mirval F1 is characterized by vigorous growth, short internodes, and a relatively short vegetation period, reaching maturity in approximately 65–70 days. The hybrid is known for producing large fruits, frequently exceeding

400 g, and for its good adaptation to greenhouse conditions, particularly during periods of elevated temperatures. These characteristics suggest a strong productive potential and explain why Mirval F1 is often preferred in intensive production systems aimed at maximizing yield.

Black Pearl F1, on the other hand, follows a somewhat different production pattern. The plants show moderate vigor and require a slightly longer growing period, but they produce fruits with a distinctive appearance and a fleshy, juicy texture that is highly appreciated by consumers. Although the average fruit weight is lower than that of Mirval F1, the cultivar is recognized for its stable performance and marketable fruit quality.

The contrast between the two cultivars was one of the reasons for their inclusion in the study. Mirval F1 represented a highly productive genotype with strong vegetative growth, whereas Black Pearl F1 offered an opportunity to evaluate how a less vigorous cultivar responds to grafting and fertilization. This variability was expected to provide a broader perspective on the effectiveness of the technological factors investigated and to reveal possible genotype-specific responses throughout the experiment.

Crop Management, Measurements and Laboratory Analyses

All plants were cultivated under the same management conditions throughout the experiment. Irrigation, ventilation, crop maintenance, and plant protection measures were applied uniformly across all treatments in order to reduce the influence of external factors on plant performance. Maintaining similar growing conditions was particularly important because the objective of the study was to evaluate the effects of cultivar, rootstock, and fertilization regime rather than differences caused by environmental variation within the greenhouse.

The cultivation program also included Cytoplant 400 (DAYMSA, Spain), a biostimulant based on natural cytokinins. Applications were carried out during periods of active vegetative growth and fruit development according to the recommendations provided by the manufacturer. The inclusion of this product was intended to support plant physiological activity throughout the growing cycle, especially during stages characterized by intensive growth and high nutrient demand.

Productivity was assessed using the parameters most commonly considered in commercial eggplant production. Average fruit weight was determined from representative fruits collected at harvest, while fruit number was recorded for each plant during the production period. Total yield was subsequently calculated and expressed on a hectare basis. These indicators were chosen because they reflect both the productive capacity of the plants and the practical value of the crop under commercial growing conditions.

Examining fruit weight together with fruit number also made it possible to better understand the mechanisms behind yield formation. In many cases, increases in productivity may result from larger fruits, a greater number of fruits, or a combination of both. Evaluating all three parameters therefore provided a more complete picture of how the different technological combinations influenced crop performance during the experimental period.

Physiological measurements were performed throughout the growing season in order to monitor how the different grafting and fertilization treatments influenced plant functioning. Because productivity is closely linked to photosynthetic activity and resource utilization, gas-exchange measurements were included to provide additional information beyond the agronomic data collected in the field.

The evaluations were carried out using an LCpro T portable photosynthesis system (ADC BioScientific Ltd., United Kingdom) and a CCM-200 Plus chlorophyll meter (Opti-Sciences Inc., USA). Net photosynthetic assimilation rate (A), transpiration rate (E), stomatal conductance (gs), internal CO_2 concentration (Ci), leaf temperature (Tl), and photosynthetic photon flux (Qleaf) were recorded. Together, these measurements provided information on carbon assimilation, water relations, and the overall physiological status of the plants under the different technological combinations.

Physiological evaluations were complemented by laboratory analyses performed on fruits collected at commercial maturity. Antioxidant activity was determined using the DPPH and ABTS methods, while total polyphenol content, tannin concentration, and chlorophyll content were quantified using standard analytical procedures.

The inclusion of these biochemical determinations was intended to extend the evaluation beyond yield performance alone. Eggplant is recognized as a valuable source of antioxidant compounds, and changes in fruit composition can provide useful information regarding the influence of cultivation practices on nutritional quality (Niño-Medina et al., 2017). Assessing productivity, physiological activity, and fruit composition within the same experiment made it possible to examine crop responses from several complementary perspectives and to obtain a more complete picture of the effects associated with the investigated technological factors.

Statistical Processing of Data

The data collected during the experiment were statistically processed to evaluate the effects of cultivar, rootstock, fertilization regime, and their interactions on the investigated traits. Because the study included several treatment combinations and multiple categories of measurements, statistical analysis was necessary to determine whether the observed differences reflected real treatment effects rather than random variation among plants.

Analysis of variance (ANOVA) was used to compare the experimental variants and identify significant sources of variation. Whenever significant differences were detected, treatment means were separated using the Least Significant Difference (LSD) test at the 5% significance level ($p \leq 0.05$). This made it possible to compare the performance of the different technological combinations and to identify those that consistently produced superior agronomic, physiological, or biochemical responses.

Relationships among productivity indicators, photosynthetic parameters, and fruit quality traits were further explored through correlation analyses. Examining these associations helped place the results into a broader biological context and provided a better understanding of how changes in plant physiology were reflected in yield formation and fruit composition. Statistical calculations were performed using Microsoft Excel together with software routinely used in horticultural research.

Table 2

Experimental design and workflow of the study

Methodological Stage	Tools and Resources	Outputs
Literature review	Scientific publications and databases	Research hypotheses
Selection of experimental factors	Hybrids, rootstocks, fertilization variants	Experimental scheme
Field establishment	Split-plot design, irrigation system	72 plots
Application of treatments	Biological, organic and chemical inputs	Experimental variants
Periodic observations	Observation sheets and measurements	Growth data
Data collection	Laboratory analyses and field records	Databases
Statistical processing	ANOVA and correlation analyses	Statistical significance
Agronomic determinations	Yield and biometric measurements	Productivity indicators
Physiological determinations	LCpro T and CCM-200 Plus	Physiological indices

The stages presented in Table 2 illustrate the sequence followed throughout the experiment, from the selection of biological material and treatment combinations to data collection, laboratory analyses, and statistical interpretation. Although each stage addressed a different aspect of the research process, all activities were closely connected and contributed to the same objective: understanding how cultivar, rootstock, and fertilization strategy interact to influence crop performance under protected cultivation conditions.

Particular attention was given to the integration of field observations with physiological and biochemical evaluations. Productivity measurements alone can provide valuable information regarding the commercial performance of a crop, but they often offer only a partial explanation of the responses observed in the field. For this reason, agronomic assessments were complemented by measurements of photosynthetic activity, gas exchange, antioxidant capacity, and bioactive compound accumulation. Evaluating these components simultaneously allowed a more comprehensive interpretation of plant responses and helped identify the physiological and biochemical processes associated with differences in yield and fruit quality.

The experimental workflow was designed to move progressively from observation to interpretation. Data collected during the growing season were linked with laboratory determinations and subsequently examined through statistical analyses, making it possible to identify not only significant treatment effects but also relationships among productivity, plant physiology, and fruit composition. This integrated approach provided a broader perspective on crop behavior and facilitated the identification of technological combinations capable of improving both productivity and quality.

By combining agronomic, physiological, and biochemical information within the same experimental framework, the study aimed to generate a more complete understanding of how grafting, fertilization practices, and cytokinin-supported crop management influence eggplant cultivation. Such an approach is particularly relevant for modern horticulture, where production systems are increasingly evaluated not only by their yield potential but also by their efficiency, sustainability, and ability to produce fruits with enhanced nutritional value.

RESULTS AND DISCUSSIONS

Yield and Productivity Response

The productivity data clearly showed that neither grafting nor fertilization acted independently. Plant performance varied considerably depending on the combination of cultivar, rootstock, and nutrient management strategy, suggesting that the response of eggplant is largely driven by the interaction among these factors rather than by any single technological intervention.

Looking more closely at the data, it became evident that the same fertilization regime did not always produce similar responses when associated with different rootstocks or cultivars. Likewise, the advantages of grafting were expressed to different degrees depending on the nutritional conditions under which the plants were grown. This variability indicates that yield formation in eggplant is influenced by a network of interconnected factors that operate throughout the growing cycle.

The productive potential of a cultivar establishes the basis for yield formation, but the extent to which that potential is expressed depends largely on the capacity of the root system to support plant growth and on the availability of nutrients during critical developmental stages. For this reason, some treatment combinations consistently outperformed others, particularly when vigorous rootstocks were combined with biologically based fertilization strategies.

Rather than identifying a single factor responsible for the observed differences, the results point toward a cumulative effect generated by the interaction of cultivar characteristics, rootstock performance, and nutrient management. Under the conditions of the present experiment, the most productive treatments were those in which these components complemented each other, resulting in a more balanced and efficient use of available resources.

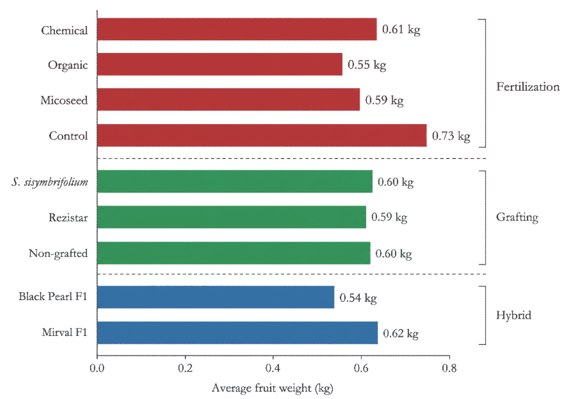

Figure 1a. **Productivity parameters regarding the average fruit weight as influenced by hybrid, grafting, and fertilization**

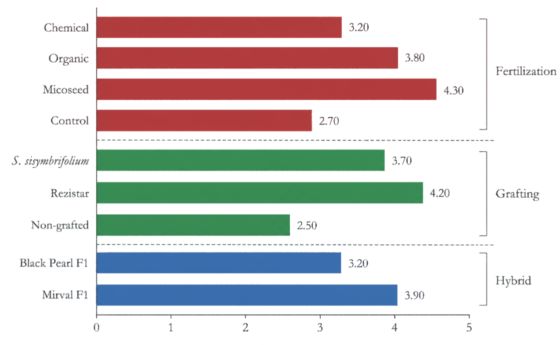

Figure 1b. **Productivity parameters regarding the average fruit weight as influenced by hybrid, grafting, and fertilization**

Across almost all treatments, grafted plants produced higher yields than non-grafted controls, highlighting the important contribution of rootstock selection to crop performance. The advantage was particularly evident when Rezistar F1 was used as rootstock. Throughout the growing season, plants grafted onto Rezistar F1 maintained a more vigorous canopy, showed a greater capacity to sustain fruit development, and ultimately produced a larger number of marketable fruits. These responses suggest that the enhanced root system improved the plant's ability to acquire and utilize available water and nutrients, creating more favorable conditions for continuous growth and reproductive development.

The influence of fertilization was equally apparent, although its effect varied depending on the grafting combination. Micoseed consistently generated some of the highest values for fruit number and total yield, while organic fertilization frequently produced very similar responses. This finding is particularly interesting because it indicates that biologically based fertilization strategies can support high productivity levels without relying exclusively on conventional chemical inputs. Although chemical fertilization promoted vigorous vegetative growth, this did not always translate into a proportional increase in yield, suggesting that excessive vegetative development is not necessarily associated with greater reproductive performance.

One of the most notable observations was that yield increases were driven primarily by fruit number rather than fruit size. Average fruit weight remained relatively stable among treatments, whereas the number of fruits per plant increased considerably in the grafted variants. This pattern points to a positive effect of grafting on flowering, fruit set, and fruit retention, processes that are particularly sensitive to plant physiological status. A more efficient root system likely improved the supply of water, nutrients, and assimilates during critical developmental stages, reducing fruit abortion and supporting the formation of a larger number of marketable fruits.

Taken together, these results emphasize that productivity gains were not the consequence of a single technological factor. Instead, they resulted from the interaction between cultivar characteristics, rootstock performance, and fertilization strategy. The superior performance observed in the grafted treatments illustrates how improvements in root functionality can influence the entire production process, from vegetative growth and resource acquisition to fruit formation and final yield.

Table 3

Productive performance of the most relevant technological combinations

Experimental Combination (Hybrid × Rootstock × Fertilization)	No. of fruits/plant	Average fruit weight (kg)	Yield (kg/ha)
Mirval F1 × Rezistar F1 × Micoseed	6.2	0.59	112,485
Mirval F1 × Rezistar F1 × Organic	5.9	0.6	110,792
Mirval F1 × *S. sisymbriifolium* × Micoseed	5.6	0.58	108,053
Black Pearl F1 × Rezistar F1 × Organic	5.1	0.57	97,642
Mirval F1 × Non-grafted × Micoseed	3	0.61	58,427
Black Pearl F1 × Non-grafted × Organic	2.8	0.6	54,318

Among all variants, Mirval F1 grafted onto Rezistar F1 and fertilized with Micoseed achieved the best overall performance, exceeding 112 t ha^{-1} and producing an average of 6.2 fruits per plant. Similar values were obtained under organic fertilization, which is particularly important from a sustainability perspective. The relatively small difference between these two treatments suggests that biologically based fertilization can support intensive production without compromising productivity.

Taken together, the productivity results underline the importance of combining vigorous genetic material with efficient rootstocks and balanced nutrient management. Under the conditions of the present experiment, these factors worked together to create a production system capable of maintaining both high yields and crop stability.

Photosynthetic Performance and Plant Physiology

The physiological data followed a trend that was largely consistent with the productivity results discussed earlier. Treatments that produced more fruits and higher yields were generally associated with greater photosynthetic activity and a more efficient regulation of gas exchange. This suggests that the productive advantages observed in the field were not accidental but were supported by measurable differences in

plant functioning throughout the growing season.
Clear differences emerged among cultivars, rootstocks, and fertilization regimes for several physiological parameters. Variations in photosynthetic assimilation, stomatal conductance, transpiration, and internal CO_2 concentration indicate that the evaluated treatments influenced the way plants acquired and utilized available resources. In many cases, the grafted variants maintained a more favorable physiological balance, particularly during periods of intensive growth and fruit development.
An interesting aspect was the close relationship between physiological performance and yield formation. Plants that maintained higher photosynthetic rates and more efficient gas exchange generally supported a greater number of fruits and achieved higher productivity. This pattern was observed repeatedly across the experiment and helps explain part of the advantage associated with grafting and biologically based fertilization strategies.
Taken together, the physiological measurements offer a better understanding of the mechanisms underlying the agronomic responses observed in the field. They show that improvements in productivity were accompanied by changes in photosynthetic efficiency and resource utilization, highlighting the importance of physiological regulation in modern eggplant production systems.

Table 4
Comparison of photosynthetic performance under different technological combinations

Parameter	Best Performing Hybrid and Rootstock	Results
Net assimilation (A)	Mirval × *S. sisymbriifolium*	Reaches the highest values, with clear differences compared to ungrafted Mirval and Black Pearl.
Transpiration (E)	Black Pearl × *S. sisymbriifolium*	Highest values recorded, indicating increased water cost. The biological regime maintains the best A/E balance.
Stomatal conductance (gs)	Mirval × *S. sisymbriifolium*	Stomata open the most, allowing optimal CO_2 diffusion.
Internal CO_2 concentration (Ci)	Black Pearl (ungrafted, chemical)	Highest values, but reflect less efficient CO_2 utilization; the biological regime ensures the best utilization/diffusion ratio.
Leaf temperature (Tl)	Mirval control	Maintains the leaf at optimal values, without overheating; the chemical regime increases Tl by 1–2 °C.
Photosynthetic flux (Qleaf)	Black Pearl × *S. sisymbriifolium*	Highest flux values, but the biological regime uses available radiation more efficiently.

The highest photosynthetic assimilation rates were recorded in Mirval F1 grafted onto Solanum sisymbriifolium, particularly under chemical fertilization. The same treatment also showed elevated stomatal conductance, suggesting a greater capacity to absorb and utilize atmospheric carbon dioxide. These responses are consistent with the improved vigor commonly reported for grafted plants and likely reflect the enhanced ability of the root system to supply water and nutrients to the canopy.

An interesting contrast emerged when internal CO_2 concentration was examined. The highest values were measured in some non-grafted plants, yet these treatments did not exhibit superior photosynthetic performance. This suggests that carbon dioxide was not being utilized as efficiently, reinforcing the idea that physiological efficiency depends not only on gas availability but also on the plant's ability to convert that carbon into assimilates.

Transpiration and leaf temperature provided additional insight into plant functioning. Although chemical fertilization frequently generated the highest physiological values, biological fertilization produced a more balanced response overall. Plants maintained favorable photosynthetic activity while avoiding excessive water loss, an aspect that becomes increasingly important under conditions of environmental stress.

The role of Cytoplant 400 should also be considered when interpreting these responses. Cytokinins are known to support chlorophyll retention, delay leaf aging, and maintain photosynthetic activity for longer periods. While the individual contribution of the biostimulant cannot be separated from the other technological factors, the overall physiological performance observed in the grafted treatments is consistent with the effects commonly associated with cytokinin-based products.

From a practical point of view, the physiological data help explain why grafted plants were able to sustain higher productivity. Increased photosynthetic activity, improved stomatal regulation, and better resource utilization created favorable conditions for continuous fruit development throughout the growing season.

Fruit Quality and Bioactive Compounds

In recent years, discussions surrounding vegetable quality have extended well beyond appearance and marketable yield. For crops such as eggplant, attention is increasingly directed toward the compounds that contribute to nutritional value and antioxidant potential, particularly because these attributes are often associated with consumer perception of product quality. Polyphenols, tannins, chlorophyll-related pigments, and other bioactive compounds are among the components most frequently used to characterize the functional value of eggplant fruits (Plazas et al., 2013; Stommel et Whitaker, 2003).

The accumulation of these compounds is influenced by several interacting factors. Genetic background plays an important role, but cultivation practices can also modify metabolic activity and, ultimately, fruit composition. Grafting and fertilization are especially relevant in this regard, as both have the potential to affect nutrient uptake, physiological balance, and the synthesis of secondary metabolites. For this reason, evaluating fruit quality together with productivity offers a more realistic assessment of the overall performance of a cultivation system.

A noticeable trend emerged across the evaluated treatments. In many cases, grafted plants produced fruits with higher antioxidant activity and a more favorable biochemical profile than non-grafted controls. This suggests that the benefits associated with grafting are not limited to yield formation alone and may also influence the nutritional characteristics of the harvested fruits. Such responses are particularly important in modern horticulture, where increasing productivity is expected to occur alongside improvements in product quality rather than at its expense.

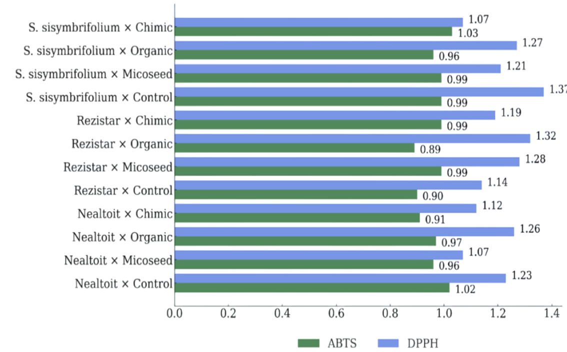

Figure 3. **Antioxidant activity under different grafting and fertilization combinations**

The antioxidant activity of the fruits varied considerably among the evaluated treatments, but one pattern appeared repeatedly throughout the experiment. In most cases, fruits harvested from grafted plants showed higher antioxidant values than those obtained from non-grafted controls. The advantage became particularly evident when Rezistar F1 or Solanum sisymbriifolium were combined with Micoseed or organic fertilization, suggesting a positive interaction between rootstock performance and biologically based nutrient management.

Interestingly, the increase in antioxidant activity was accompanied by similar changes in other quality-related parameters. Treatments that recorded higher antioxidant values also tended to accumulate greater amounts of polyphenols, tannins, and chlorophyll-related compounds. This relationship suggests that the technological combinations promoting stronger physiological activity were also more effective in stimulating the synthesis and accumulation of secondary metabolites associated with fruit quality.

From a practical perspective, these results are important because they show that the improvements obtained through grafting were not limited to productivity alone. In several cases, the same treatments that supported higher yields also produced fruits with a richer biochemical profile, indicating that productivity and quality can be improved simultaneously when appropriate rootstocks and fertilization strategies are combined.

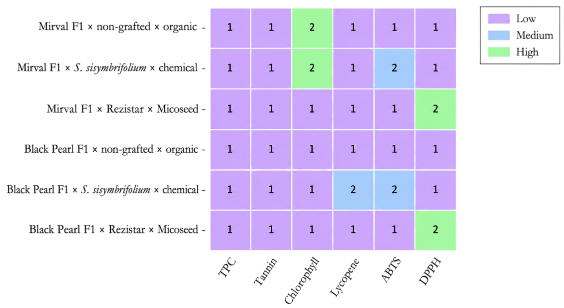

Figure 4. **Variation of biochemical parameters as affected by cultivar, rootstock, and fertilization regime**

Higher concentrations of these compounds were usually associated with the grafted variants, suggesting that rootstock effects extended well beyond productivity alone. Improved nutrient acquisition and greater physiological stability likely created favorable conditions for secondary metabolite synthesis, leading to a richer biochemical profile.

Perhaps the most relevant outcome is that improvements in fruit quality did not occur at the expense of productivity. In many production systems, increasing yield is often accompanied by a reduction in quality-related compounds. Such a trade-off was not evident here. The treatments that produced the highest yields also maintained elevated concentrations of antioxidants and phenolic compounds.

This result has important practical implications. It suggests that growers do not necessarily have to choose between productivity and quality. When grafting, biological fertilization, and cytokinin-supported crop management are combined appropriately, both objectives can be achieved simultaneously.

Overall, the results point toward a common conclusion: the most successful technological combinations were those capable of improving plant performance at multiple levels. Higher productivity, stronger physiological activity, and enhanced fruit quality were not isolated responses but interconnected outcomes of the same integrated cultivation strategy.

CONCLUSIONS

The work presented here explored how cultivar, rootstock, and fertilization strategy shape the agronomic, physiological, and biochemical behavior of eggplant grown under protected conditions within a crop management program supported by Cytoplant 400 (DAYMSA, Spain). Rather than acting independently, these factors interacted continuously throughout the growing cycle, influencing not only productivity but also plant functioning and fruit composition.

A consistent advantage of grafting became evident across most of the evaluated parameters. Both Rezistar F1 and Solanum sisymbriifolium improved plant performance when compared with non-grafted controls, although their effects were not identical. Rezistar F1 was more closely associated with higher productivity, whereas S. sisymbriifolium frequently stood out for its positive influence on physiological activity and fruit quality attributes.

The response to fertilization followed a similar pattern. Micoseed and organic fertilization repeatedly produced some of the most balanced results, supporting high yields while also favoring the accumulation of compounds associated with nutritional and functional quality. This was particularly noticeable in the grafted variants, where biological fertilization often matched or even exceeded the performance of conventional chemical inputs.

Among all treatment combinations, Mirval F1 grafted onto Rezistar F1 and fertilized with Micoseed proved to be the most productive, surpassing 112 t ha^{-1} and producing the highest number of fruits per plant. What makes this result especially relevant is that the increase in yield was accompanied by favorable physiological and biochemical responses rather than being achieved at the expense of fruit quality.

The physiological measurements helped explain these differences. Plants that yielded more were generally those that maintained stronger photosynthetic activity, more efficient gas exchange, and a better overall physiological balance throughout the season. At the same time, fruits harvested from grafted plants, particularly those receiving biological fertilization, showed higher antioxidant activity together with increased concentrations of polyphenols, tannins, and chlorophyll-related compounds.

Taken together, the results suggest that the greatest benefits were obtained when grafting, biologically oriented fertilization, and cytokinin-supported crop management were combined within the same production system. Under the conditions of this study, such an approach improved productivity while also enhancing fruit quality, highlighting its potential as a practical strategy for more sustainable eggplant cultivation.

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