QUALITY ATTRIBUTES OF EGGPLANT VARIETIES GROWN UNDER DIFFERENT FERTILIZATION REGIMES

ATRIBUTELE DE CALITATE ALE VARIETĂȚILOR DE PĂTLĂGELE VINETE CULTIVATE SUNB INFLUENȚA UNOR REGIMURI DIFERITE DE FERTILIZARE

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Abstract.
Eggplants is an excellent nutritionally vegetable in all parts of the world, and it is extensively consumed, thus it has a considerable impact on the horticultural industry. The purpose of this study was to assess the qualitative of Two hybrid varieties (Mirval and Black Pearl) cultivated under various fertilization and farming regimes, with a focus on nutritional and antioxidant capabilities. The experiment was carried out on the farm of the Iasi University of Life Sciences in Romania, utilizing different agronomic techniques. A total of 8 version were cultivated using four different fertilization treatments: organic, chemical, control, and biological. Following harvesting, analyses were performed at the Andalusian Institute in Cordoba, Spain, using advanced laboratory modern. Quality and safety markers such as chlorophyll a, chlorophyll b, lycopene, beta-carotene, tannins, total polyphenols, and antioxidant activity (ABTS, DPPH assays) were assessed. The results showed significant variations between fertilization procedures. For example, the biofertilisation treatment produced the highest total polyphenol content, but the control group demonstrated modest antioxidant activity. Chlorophyll levels and carotenoid content also varied with cropping methods, demonstrating that fertilisation types had a significant impact on eggplant quality. This study examines the effects of planting schemes and irrigation regimes on the nutritional and phytochemical properties of eggplant, promoting sustainable agricultural methods that improve crop quality.

Keywords: eggplant, quality attributes, irrigation systems, fertilization types

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Rezumat.
Vinetele sunt o legumă excelentă din punct de vedere nutrițional în toate părțile lumii și sunt consumate pe scară largă, având astfel un impact considerabil asupra industriei horticole. Scopul acestui studiu a fost de a evalua calitatea a două soiuri hibride (Mirval și Black Pearl) cultivate în diferite regimuri de fertilizare și agricultură, cu accent pe capacitățile nutriționale și antioxidante. Experimentul a fost realizat la ferma Universităţii de Ştiinţe ale Vieţii din Iaşi din România, utilizând diferite tehnici agronomice. Un total de 8 versiuni au fost cultivate folosind patru tratamente diferite de fertilizare: organice, chimice, de control și biologice. În urma recoltării, au fost efectuate analize la Institutul Andaluz din Cordoba, Spania, folosind un laborator modern avansat. Au fost evaluați markerii de calitate și siguranță, cum ar fi clorofila a, clorofila b, licopenul, beta-carotenul, taninurile, polifenolii totali şi activitatea antioxidantă (ABTS, testele DPPH). Rezultatele au arătat variații semnificative între procedurile de fertilizare. De exemplu, tratamentul de biofertilizare a produs cel mai mare conținut total de polifenoli, dar grupul de control a demonstrat o activitate antioxidantă modestă. Nivelurile de clorofilă și conținutul de carotenoide au variat, de asemenea, cu metodele de recoltare, demonstrând că tipurile de fertilizare au avut un impact semnificativ asupra calității vinetelor. Acest studiu examinează efectele schemelor de plantare și ale regimurilor de irigare asupra proprietăților nutriționale și fitochimice ale vinetelor, promovând metode agricole durabile care îmbunătățesc calitatea culturilor.
Cuvinte cheie: vinete, atribute de calitate, sisteme de irigare, tipuri de fertilizare

INTRODUCTION

Eggplants are grown mainly in the subtropics, where they account for 94% of world production. It is nicknamed ‘the king of vegetables’ because of its great popularity. So, it is an important part of the economy. According to the Food and Agriculture Organization of the United Nations [Caruso et al., 2017], China and India are the world's leading producers of auberges (28 and 13 Mt per year, respectively). In Europe, auberge cultivation is mainly concentrated in Turkey (827.000 t), Italy (220.000 t), Spain (206.000 t) and Romania (123.000 t/year) [Caruso *et al*., 2017]. According to FAO figures, eggplant rank sixth in total world production, behind tomatoes, watermelons, onions, cucumbers and cabbages, with 52.3 million tonnes produced in 2017 (Plazas et al., 2019]. Eggplants are also one of the 35 food crops considered to be the most important for global food security, and as such are included in Annex 1 of the International Treaty on Plant Genetic Resources for Food and Agriculture [Plazas *et al*., 2019]. Eggplants have a unique gastronomic and economic impact because of their great ecological plasticity, their appeal to consumers and their adaptability to different growing systems [Ciubotarita *et al*., 2022]. The fruit is rich in sugar, carbohydrates, protein and vitamin C, making it both tasty and nutritious. Canneries account for around 65-

70% of total production. Eggplant can be prepared in a variety of ways, including cooking, canning, stuffing, marinating, and frying [Kostadinov *et al*., 2019]. Eggplant is not expensive so it is in the diet of low-income consumers [Gürbüz *et al*., 2018]. This plant is gaining in popularity because of its high concentration of antioxidants (phenolic acids), which are beneficial to human health [Gajewski *et al*., 2009]. Eggplant is used in traditional medicine to treat a variety of ailments. For example, in certain regions of Asia, the vegetative aerial parts of S. Americanum/nigrum were traditionally used to treat skin ailments, as a purgative, to facilitate urination and to stimulate the libido [Meyer *et al*., 2014]. Nutrients affect the growth and development of Eggplant. Over the last 30 years, new varieties and hybrids have appeared on the Romanian market, but they have often failed to adapt to changing environmental conditions and consumer tastes. A recent study showed that the main elements influencing the quantity and quality of the harvest in organic and conventional systems are the cultivar, fertilizer and irrigation [Ciubotarita *et al*., 2022]. The area of farmland managed organically, the number of organic farms and the global market for organic products have all increased progressively. The most recent data suggests that this trend has been amplified by a sharp increase in consumer demand for organic food during the COVID-19 epidemic [Fernández *et al*., 2022]. The development of organic production has made it possible to produce food crops of superior nutritional quality while using fewer external inputs and reducing the impact on the environment [Plazas *et al*., 2019] the fertilizer applied has a direct impact on the quantity of nutrients available to plants. The use of inorganic or organic fertilizers has long been the subject of debate as to which promotes and preserves soil health in the long term [Canatoy & Daquiado, 2021]. Fertilization falls into three categories: chemical, biological and organic. It is an essential component of agricultural production. Although frequently used in agriculture, chemical fertilizers are highly controversial. Sustainable and environmentally-friendly alternatives for agriculture, such as organic and biological fertilizers, are becoming increasingly popular with farmers and consumers alike [Guilherme *et al*., 2020]. Consumers are increasingly interested in how, where and when food is produced. As a result, they are increasingly interested in organic vegetables, particularly those grown in greenhouses [Stoleru *et al*., 2019]. Greenhouses are suitable for crops that are affected by climate change, particularly in Romania due to the cold weather. So the experiment was in greenhouses in Romania. found that choosing the right cultivar and fertilizations method can result in better bioactive components in plant grown in the field under variable climatic conditions [Rusu *et al*., 2023]. The use of modern agricultural practices in crop production makes it possible to improve yield and fruit size while reducing labor costs in the fields. Therefore, in this study, we examined the effects of different fertilizations regimes and varieties on the quality and nutrient content of Two hybrid varieties (Mirval and Black Pearl) cultivars known for their adaptability to Romanian environmental conditions, pest resistance, high productivity and fruit quality. Using a different fertilization type (chemical, biological, organic and control) the experiment was carried out in a greenhouse -eggplant in a field of "V. Adamachi" Farm of Iasi University of Life Sciences (47019’25” N, 27054’99” E, 150 m altitude), during 2021-2022. We have done the analyses at the Andalusian Institute of Agriculture, Food and Animal Production (IFAPA) - Cordoba – Spain. The antioxidant activity levels (ABTS, DPPH, total polyphenols, chlorophyll A and B, lycopene of conventional and organic eggplants. This study aims to provide insights into how farming practices influence the nutritional profile of eggplant by examining antioxidant activity, polyphenol content, chlorophyll levels, lycopene and B-carotene concentrations, ratios under different systems od fertilization. Finally, the results should contribute to the development of better farming techniques and the cultivation of eggplant with a higher nutritional content.

MATERIALS AND METHODS

Plant Material and Growth Conditions

The soil is characterized as a loam-clay chernozem, with pH 7.20; electrical conductivity (EC) 482 µS·cm-2, CaCO3 0.42%, organic matter (OM) 28.32 mg·kg-1, C/N 5.87, N 2.8 g·kg-1, P 34 mg·kg-1, was used for the experiment. The biological material used was represented by two cultivars (Mirval and Black Pearl) which can react differently in climatic conditions, regarding the nutritive content in organic compounds, mineral elements, and also the yield obtained. Factor A was represented by the cultivars Mirval F1 and Black Pearl F1, Factor B – was represented by nutrition regime: B1 – Control (Ct), B2 – Micoseed® (Mo); B3 – Orgevit® (O), B4 – Nutrispore® (Ch) (Table 1).

Table 1

Sample codes and classification according to variety, fertilization system

ID	Variety F1	Fertilization
1	Mirval F1	Control
2	Black Pearl F1	Control
3	Mirval F1	Biological
4	Black Pearl F1	Biological
5	Mirval F1	Organic
6	Black Pearl F1	Organic
7	Mirval F1	Chemical
8	Black Pearl F1	Chemical

The NPK chemical fertilization (Ch) was performed with 200 kg·ha^{-1} of Nutrispore® NPK 20-20-20, applied before transplant, and two supplies of 300 kg·ha-1 of Nutrispore® NPK 9-18-27+2 MgO. Organic fertilization (O) represented by chicken manure was applied by 2000 kg·ha^{-1} of commercial Orgevit® in two phases: 1250 kg·ha^{-1} before transplant and the remainder 30 days after planting. The same amount of active substance from the two fertilizers was used, taking into account that the plants use approximately 70% of the organic fertilizer in the first year.

The biological fertilization (Mo) consisted of the application of Micoseed® at 30 kg·ha^{-1} split in two equal doses supplied before transplant and 30 days after planting, integrated with 5 L·ha^{-1} Nutryaction®, according to the company recommendations. The biological product is based on microorganisms that predominantly contain arbuscular mycorrhizal fungi spores of *Claroideoglomus etunicatum*, *Funneliformis mosseae*, *Glomus aggregatum*, *Rhizophagus intraradices*. In addition, the product is complexed with fungi and bacteria species belonging to the genera *Trichoderma* sp., *Streptomyces* sp., *Bacillus* sp., *Pseudomonas* sp. Fifty-five days old seedlings were used in the experiment. Grown in multicell trays in compliance with the organic regulation were transplanted in a greenhouse during mid-April at a density of 2.5 plants·m^{-1}. During the experiment, growing practices (training, pruning, and treatments for pests and diseases) were applied to all the plants [Stoleru *et al*., 2014]. The eggplant crop experiment ended on 31st October.

Material and sample preparation

A total of 40 eggplants were harvested from each group at the ripening stage. The samples were cut into small pieces and homogenized, then freeze-dried in an ECO EVO freeze-dryer (Tred Technology S.R.L., Ripalimosani, Italy). The dry samples were then ground and stored at -80°C until analysis.

Hydrophilic extraction

Hydrophilic extraction was carried out using a mixed solution of deionized water and methanol (20:80, v/v) with 1% formic acid. 0.2 g of freeze-dried sample was extracted with 1 mL of the extraction solvent, sonicated for 10 min in an ultrasonic bath and centrifuged at 15,000 rpm for 15 min. The supernatant was collected and the pellet re-extracted using the same protocol. The samples were transferred to vials and stored at -80°C until analysis. This extraction was used to analyze antioxidant activity, total phenolic compounds and total condensed tannins.

Antioxidant activity

The antioxidant activity of the eggplant samples was analyzed using two different tests: ABTS and DPPH using a Synergy HTX multimode microplate reader (Biotek Instruments, Winooski, VT, USA).

ABTS free radical scavenging activity was assessed in the phenolic extract according to the methods previously described by[Tuárez-García et al., 2023]. Antioxidant activity results were expressed as mmol Trolox equivalents per 100 g dry weight (mmol TE 100 g-1 DW).

The DPPH method adapted to the microplate reader [Gulcin & Alwasel, 2023]. Antioxidant activity results were expressed in mmol Trolox equivalents per 100 g dry weight (mmol TE 100 g-1 DW).

Total phenolic content

Total phenolic content was assessed using the Folin-Ciocalteau reagent according to the method of Slinkard and Singleton. The results were represented in milligrams of gallic acid equivalents per 100 grams of fresh weight (mg GAE 100 g-1 FW) [Cuevas *et al*., 2017].

Total condensed tannin content

Condensed tannins were assessed using the vanillin test described by Broadhurst and Jones [1978]. Results were represented in milligrams of catechin equivalents per 100 grams of dry weight (mg TE 100 g-1 d.w).

Pigment extraction

Lipophilic pigments were extracted using the method described by Nagata and Yamashita [1992]. Briefly, 0.2 g of freeze-dried sample was extracted in the dark with 1 ml of solvent mixed with hexane and acetone (4:6, v:v), then centrifuged at 15,000 rpm for 15 min. The supernatant was collected and the pellet re-extracted using the same protocol. Samples were transferred to vials and stored at -80°C until analysis.

Pigment analysis

The absorbance of the pigment extract was measured at 453, 505, 645 and 663 nm using a Synergy HTX multimode microplate reader (Biotek Instruments, Winooski, VT, USA). The calculation of chlorophyll a, chlorophyll b, β-carotene and lycopene content were estimated using the equations described by Nagata and Yamashita (1992).

Statistical analysis

Univariate statistical analyses were performed to identify differences between samples using Statistix v. 9.0 software. The data were subjected to an analysis of variance (ANOVA), followed by a comparison of means using Tukey's post hoc tests. The level of significance was set at $p \leq 0.05$.

RESULTS AND DISCUSSION

The nutritional and antioxidant characteristics of the two eggplant cultivars, Mirval and Black Pearl, under different fertilization regimes (organic, chemical, biological and control) proved significantly different in the study (Table 2).

Table 2

Total polyphenol content, antioxidant activity, lycopene in eggpplants

Variety	Total polyphenols	ABTS	DPPH	Lycopene
Mirval F1 x Control	2.03±0.03c	1.04±0.05ab	1.28±0.10a	2.43±0.20ab
Black Pearl F1 x Control	2.01± 0.13c	1.002±0.10ab	1.13±0.06ab	2.05±0.23b
Mirval F1 x Biological	2.60±0.06bc	0.82±0.07ab	0.91±0.06b	1.09±0.30b
Black Pearl F1 x Biological	2.05±0.18c	1.07±0.08a	1.09±0.10ab	0.43±0.07c
Mirval F1 x Organic	3.61±0.36ac	1.02±0.01ab	1.37±0.02a	3.04±0.12a
Black Pearl F1 x Organic	2.32±0.25c	0.90±0.03ab	1.30±0.08a	0.65±0.11c
Mirval F1 x Chemical	3.51±0.30ab	0.85±0.07ab	1.13±0.06ab	2.38±0.25ab
Black Pearl F1 x Chemical	2.01±0.15C	0.80±0.06b	1.12±0.07ab	0.73±0.10c
Signification for p ≤ 0.05	*	*	*	*

Total polyphenol content: Both chemically treated (3.51 ± 0.30 mg GAE/100g) and organically fertilized (3.61 ± 0.36 mg GAE/100g) samples showed significantly lower polyphenol levels than the control (2.03 ± 0.03 mg GAE/100g). Black Pearl showed consistently lower polyphenol levels; with organic fertilization, its highest value (2.32 ± 0.25 mg GAE/100g) was reached.

Antioxidant activity: Mirval achieved maximum ABTS activity in the control group (1.04 ± 0.05 mmol TE/100g) and showed the highest DPPH antioxidant activity in the organic treatment group (1.37 ± 0.02 mmol TE/100g). Organic fertilization led to lower antioxidant levels for both types, and Black Pearl showed lower antioxidant activity in all treatments.

Under organic fertilization, Mirval showed the highest levels of chlorophyll A (5.80 ± 0.63 mg/g) and chlorophyll B (8.68 ± 1.18 mg/g). Black Pearl had much lower levels of chlorophyll, particularly under chemical and organic fertilization.

Lycopene and β-Carotene: Black Pearl had the lowest lycopene concentration in the organic treatment (0.43 ± 0.07 mg/g), while organically fertilized Mirval had the highest lycopene content (3.04 ± 0.12 mg/g). A similar trend was observed for β-Carotene levels, where Mirval outperformed Black Pearl in the majority of treatments.

Tannins: Black Pearl showed reduced tannin levels in all treatments (Table 3), particularly in the organic and control groups, while organically fertilized Mirval had the highest tannin concentration (0.14 ± 0.01 mg/g).

Table 3

Chlorophyll A, B and tannin contents in eggplants

Variety	Chlorophyll A	Chlorophyll B	Tannins
Mirval F1 x Control	5.47±0.29ab	7.40±0.53a	0.09±0.00 def
Black Pearl F1 x Control	4.17±0.42b	6.24±0.90a	0.13±0.00 abc
Mirval F1 x Biological	2.36±0.36c	3.26±0.90b	0.08±0.00 ef
Black Pearl F1 x Biological	1.09±0.16c	1.29±0.23b	0.10±0.00 cde
Mirval F1 x Organic	5.80±0.63 a	8.68±1.18a	0.14±0.01 a
Black Pearl F1 x Organic	1.56±0.23c	1.84±0.23b	0.11±0.00 bcd
Mirval F1 x Chemical	5.19±0.39ab	7.25±0.75a	0.13±0.01 ab
Black Pearl F1 x Chemical	1.80±0.20c	2.20±0.30b	0.07±0.00 f
Signification for p ≤ 0.05	*	*	*

DISCUSSION

The results demonstrate the importance of fertilization practices in defining eggplant quality characteristics. The nutritional and antioxidant qualities of the Mirval variety were systematically improved by organic fertilization, while the Black Pearl variety responded less favorably to treatments.

Antioxidant activity and nutritional quality

The observation of increased antioxidant activity and polyphenol content in the organically fertilized Mirval variety raises the possibility that organic farming methods facilitate greater production of bioactive substances. These results are consistent with previous research showing that organic systems improve the nutritional profiles of crops by reducing synthetic inputs and responding to stress. The reduction in antioxidant activity and polyphenol concentration in Black Pearl may be due to variety-specific characteristics, such as genetic composition or nutrient absorption efficiency.

Pigment concentration

The increase in chlorophyll content in Mirval as a result of organic fertilization implies that this regime improves plant health and photosynthetic potential. This increase in chlorophyll content, combined with higher levels of lycopene and β-carotene, demonstrates that Mirval benefits greatly from organic and chemical fertilization in terms of yield and nutritional quality. Black pearl, on the other hand, may not respond as well to conventional fertilization techniques due to its comparatively lower pigment contents, necessitating the use of different techniques to maximize its quality.

Tannin levels

The high level of tannin concentration was found in organically fertilized Mirval eggplant, which may explain its astringency and possible health benefits. This finding implies that tannin synthesis can be influenced by organic farming methods, enhancing the nutritional value and flavor of eggplants. Black Pearl's consistently lower tannin content suggests that it may be a better choice for consumers looking for less bitter eggplants, but it may also mean fewer overall health benefits.

CONCLUSION

This study highlights the importance of type and fertilization variation in the nutritional and antioxidant qualities of eggplant. The Mirval type, particularly when grown organically, showed superior polyphenol content, antioxidant activity and pigment levels, making it a good candidate for high-quality eggplant production. In contrast, the Black Pearl variety showed lower nutritional benefits in most treatments, implying that additional fertilization procedures may be required to improve its performance.

These results support the use of organic fertilizers to promote sustainable farming practices while improving eggplant nutrition. Further research is needed to investigate other aspects such as irrigation systems and soil health, which may influence eggplant quality and production in different growing situations.

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