Increase in pigments and stomatal conductance of murta (*Ugni molinae*) through applications of organic-based fertilizer[1]

Aumento de pigmentos y conductancia estomática de murta (*Ugni molinae*) mediante aplicaciones de fertilizantes de base orgánica

Aumento de pigmentos e condutância estomática em murta (*Ugni molinae*) através da aplicação de fertilizantes orgânicos

Matías Betancur*[2], Andrés Pinto-Poblete*[3], Sergio Moraga-Bustos*[4], Constanza García-Castillo*[5], Fernando Pinto-Morales*[6], Isabel Barrena-Merino*[7], José Leyton*[8], Yessica Andrea Rivas Tisnao*[9], Marco Fernández*[10]
Universidad Adventista de Chile*

Autor de correspondencia: Matías Betancur, matiasbetancur@unach.cl

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Abstract

Introduction: *Ugni molinae*, known as murta, is a shrub native to Chile with medicinal and food applications. Organic soil fertilization can influence plant development; however, its effect on murta remains poorly studied. **Objective:** The objective of this research was to evaluate the effect of increasing compost doses on soil chemical properties and physiological and morphological variables of murta plants. **Methods:** The study was conducted during the 2022 season in an established orchard at Universidad Adventista de Chile, Ñuble Region, Chile, on a volcanic Typic Melanoxerand soil. A randomized complete block design was used, with four treatments corresponding to 0, 5, 10, and 15 t ha^{-1} of compost, considering 16 plants in total and four replicates per treatment. Available macronutrients, soil organic matter, stomatal conductance, maximum quantum yield of photosystem II, plant height, branch length, and leaf

[2] https://orcid.org/0000-0003-0762-7175
[3] https://orcid.org/0000-0001-5124-9621
[4] https://orcid.org/0009-0007-7491-6141
[5] https://orcid.org/0009-0000-3349-034X
[6] https://orcid.org/0000-0001-6999-2077
[7] https://orcid.org/0009-0008-9280-7958
[8] https://orcid.org/0009-0005-8978-4706
[9] https://orcid.org/0000-0002-1172-9775
[10] https://orcid.org/0009-0008-8145-1087

pigments were evaluated. **Results:** The 10 t ha^{-1} dose increased nitrogen availability, stomatal conductance at 12:00 h, and anthocyanin content. In contrast, 15 t ha^{-1} increased soil organic matter, plant height, and branch length, but reduced flavonoid content. **Conclusions:** It was concluded that the 10 t ha^{-1} dose was the most suitable for promoting the physiological development of murta.

Keywords: Agriculture; Agricultural chemistry; Phytochemistry; Photosynthesis; Organic matter.

Resumen

Introducción: *Ugni molinae*, conocido como murta, es un arbusto nativo de Chile con aplicaciones medicinales y alimentarias. La fertilización orgánica puede influir en el desarrollo vegetal; sin embargo, su efecto en murta aún ha sido poco estudiado. **Objetivo:** El objetivo de esta investigación fue evaluar el efecto de dosis crecientes de compost sobre propiedades químicas del suelo y variables fisiológicas y morfológicas de plantas de murta. **Métodos:** El estudio se realizó durante la temporada 2022 en un huerto establecido en la Universidad Adventista de Chile, Región de Ñuble, Chile, sobre un suelo volcánico Typic Melanoxerand. Se utilizó un diseño de bloques completos al azar, con cuatro tratamientos correspondientes a 0, 5, 10 y 15 t ha^{-1} de compost, considerando 16 plantas en total y cuatro repeticiones por tratamiento. Se evaluaron macronutrientes disponibles, materia orgánica del suelo, conductancia estomática, rendimiento cuántico máximo del fotosistema II, altura de planta, longitud de rama y pigmentos foliares. **Resultados:** La dosis de 10 t ha^{-1} aumentó la disponibilidad de nitrógeno, la conductancia estomática a las 12:00 h y el contenido de antocianinas. En contraste, 15 t ha^{-1} incrementó la materia orgánica del suelo, la altura y longitud de ramas, pero redujo el contenido de flavonoides. **Conclusiones:** Se concluyó que la dosis de 10 t ha^{-1} fue la más adecuada para favorecer el desarrollo fisiológico de murta.

Palabras clave: Agricultura; Química agrícola; Fitoquímica; Fotosíntesis; Materia orgânica.

Resumo

Introdução: *Ugni molinae*, conhecida como murta, é um arbusto nativo do Chile com aplicações medicinais e alimentares. A fertilização orgânica do solo pode influenciar o desenvolvimento das plantas; no entanto, seu efeito na murta ainda é pouco estudado. **Objetivo:** O objetivo desta pesquisa foi avaliar o efeito de doses crescentes de composto sobre propriedades químicas do solo e variáveis fisiológicas e morfológicas de plantas de murta. **Métodos:** O estudo foi realizado durante a temporada de 2022 em um pomar estabelecido na Universidad Adventista de Chile, Região de Ñuble, Chile, sobre um solo vulcânico Typic Melanoxerand. Foi utilizado um delineamento em blocos completos casualizados, com quatro tratamentos correspondentes a 0, 5, 10 e 15 t ha^{-1} de composto, considerando 16 plantas no total e quatro repetições por tratamento. Foram avaliados macronutrientes disponíveis, matéria orgânica do solo, condutância estomática, rendimento quântico máximo do fotossistema II, altura da planta, comprimento do ramo e pigmentos foliares. **Resultados:** A dose de 10 t ha^{-1} aumentou a disponibilidade de nitrogênio, a condutância estomática às 12:00 h e o teor de antocianinas. Em contraste, 15 t ha^{-1} aumentou a matéria orgânica do solo, a altura da planta e o comprimento dos ramos, mas reduziu o teor de flavonoides. **Conclusões:** Concluiu-se que a dose de 10 t ha^{-1} foi a mais adequada para favorecer o desenvolvimento fisiológico da murta.

Palavras Chave: Agricultura; Química agrícola; Fitoquímica; Fotossíntese; Matéria orgânica.

Introduction

Ugni molinae, known as Murta or murtilla, is a perennial shrub native to South America, particularly Chile and Argentina (Espinoza-Tellez et al., 2021). Murta has diverse uses, including both culinary and medicinal applications (Fredes et al., 2020). Its fruits, which are reddish in color and sweet and sour in flavor, are widely used in the preparation of products such as jams, jellies, and drinks, which have generated a growing market (Seguel et al., 2000). The murta, which grows in the wild and presents a high capacity for adaptation to various climatic conditions and types of soil, has become an attractive option for the implementation of orchards and fruit production in sustainable agricultural systems (López et al., 2018). However, similar to any fruit tree, it faces productive challenges that require attention. These challenges include the implementation of sustainable management practices to optimize the development of the plant and, consequently, the quality of the fruit and production (Torrego et al., 2018).

Fertilization promotes the vegetative and productive development of species, including native species with rustic characteristics (Arena et al., 2020). Inorganic fertilizers and their excessive use generate alterations in soil pH, which is particularly notable in the case of ammonia fertilizers (Liu et al., 2023a). Modification of pH leads to an increase in the salt content of the soil, generating an increase in electrical conductivity that negatively affects the quality and health of the soil, affecting the availability of nutrients for plants and their productivity (Vargas-Pineda et al., 2019). Additionally, acidification of soil decreases the bioavailability of some soil nutrients, such as P, and increases the bioavailability of elements that are toxic to biological activity, such as Al (Bravo et al., 2017). Inorganic fertilizer use decreases the biodiversity of soil microorganisms and macroorganisms that perform vital functions, such as the decomposition of organic matter (OM), fixation of N, biogeochemical cycles of nutrients, and function of natural enemies against pests and diseases (Aguilar-Paredes et al., 2023).

Organic fertilization with compost is beneficial to the soil in multiple ways, as it improves its physical, chemical, and biological properties (Ahmad et al., 2021). In addition, compost is easy to prepare and inexpensive because it allows the reuse of a wide variety of waste (Rashid & Shahzad, 2021). The input of organic matter by compost acts as a habitat for microorganisms, provides nutrients, and facilitates essential processes, such as soil aggregation, improving porosity, infiltration, and water retention (Jaimes-Díaz et al., 2021). Soil improvements caused by compost include increased physiological and vegetative development of plants. For example, compost application in a *Berberis microphylla* G. Forst orchard provided OM and nutrients (N, P, and K) to the soil, which improved physiological performance and photosynthesis (Pinto-Morales et al., 2022). In lettuce, increased the content of pigments such as flavonoids, which are important in the natural defense of the plant, and antioxidants for human health (Giménez et al., 2020). However, the effects of compost should be evaluated in depth, as cell and vegetative growth can lead to pigment depletion. For example, in a vineyard, compost application increased fruit volume, but decreased anthocyanin content (Cataldo et al., 2023).

There is no evidence on the effects of compost application in cultivated murta orchards. This represents a relevant knowledge gap, because most available information on this species has focused on its wild growth, fruit quality, or functional properties, whereas the agronomic management required for orchard establishment remains poorly understood (Fredes et al., 2020). In particular, it is still unclear whether compost application can simultaneously improve soil fertility, plant physiological performance, vegetative growth, and leaf pigment accumulation in murta. This is especially relevant because organic amendments may enhance nutrient availability and photosynthetic functioning, but they may also modify carbon allocation patterns and alter the synthesis of secondary metabolites such as anthocyanins and flavonoids. Therefore, the objective of this study was to determine the effect of compost dose on the main soil nutrients, morpho-physiological characteristics, and leaf pigments of cultivated murta. We hypothesized that increasing compost doses would improve soil organic matter and nutrient availability, thereby promoting stomatal conductance, photosynthetic efficiency, and vegetative growth. In addition, we expected that compost application would modify leaf pigment content, with higher doses favouring the accumulation of anthocyanins and flavonoids due to improved plant nutritional status. This study contributes to identifying an appropriate compost dose for improving the physiological and vegetative development of murta under orchard conditions.

Materials and methods

Experimental setup

The study was conducted at the Universidad Adventista de Chile (UnACh), located at Kilometer 12 route to Tanilvoro, province of Chillán, Ñuble Region (36310 S; 71 540 W), Chile. The site of the study was volcanic soil (Typic Melanoxerand) (Natural Resources Conservation Service, 2010), with a temperate Mediterranean climate, hot and dry summers, and cold and humid winters, with an annual precipitation of 920,1 mm concentrated in winter and early spring (Instituto de Investigaciones Agropecuarias, 2022).

The study was carried out in a murta orchard established in August 2022, where plants were arranged in rows, spaced one meter apart, with a three-meter gap between each row, in a total evaluation area of 0.04 ha. The orchard design consisted of randomized complete blocks, with four compost treatments corresponding to 0, 5, 10, and 15 t ha^{-1}. Each treatment included four replicates, with two experimental units per replicate, resulting in eight experimental units per treatment and 32 experimental units in total. Each experimental unit consisted of two murta plants. Treatments were randomly assigned within the experimental area to reduce the effect of spatial variability associated with field conditions. The selected compost doses represented a control without compost, a low dose, an intermediate dose, and a high dose of organic amendment. Regarding irrigation, standardization was carried out for the treatments proposed by Betancur et al. (2022) according to the daily potential evapotranspiration of the crop (ETc). The compost was obtained from the composting and recycling center of the Universidad Adventista de Chile and lasted for five months, controlling temperature, humidity, and ventilation (Sayara et al. 2020). The compost materials used were chicken manure and oat straw, mixed at a ratio of 3:1 (v/v).

Soil analysis

At the time of planting and at the end of the study, compost and soil chemical analyses were carried out at a depth of 0.30 m. Soil sampling was performed in the experimental units associated with each compost treatment, allowing the chemical response of the soil to be evaluated according to the applied dose. Soil (Table 1) and compost (Table 2) chemical analyses were carried out in the laboratory of the Universidad de Concepción using the method of Sadzawka et al. (2006) for soil organic matter (OM). Available nitrogen, phosphorus, and potassium (N, P, K) were measured using the method described by Watanabe & Olsen (1965). Soil pH was measured in water at a ratio of 1:5 (w vol^{-1}).

Table 1. Chemical analysis of the soil before treatments of compost

Parameter	Value
Available nitrogen (mg kg^{-1})	83.7
Olsen phosphorus (mg kg^{-1})	19.1
Available potassium (mg kg^{-1})	278.7
Organic matter (%)	10.2
pH	5.9

Source: Own preparation

Table 2. Chemical analysis of the compost used in the treatments

Parameter	Value
Available nitrogen (mg kg^{-1})	948.7
Organic matter (%)	26.4
Organic carbon (%)	14.7
pH	7.42
Electric conductivity (dS/m)	2.5

Source: Own preparation

Environmental characterization

For the purposes of environmental records, the photosynthetic photon flux density (PPFD, mol m^{-2} s^{-1}) was quantified at four times of the day: 09:00, 12:00, 15:00, and 18:00 h, under ambient conditions of a completely sunny day, as done by Retamal-Salgado et al. (2017). An AccuPAR LP-80 ceptometer (Decagon Devices Inc.,Washington, DC, USA) was used to measure direct photosynthetically active radiation (PAR). The PAR direct radiance evaluated from the study area started at 500 mol m^{-2} s^{-1} at 9:00 h and reached its maximum value (1700 mol m^{-2} s^{-1}) at 12:00 h (Figure 1).

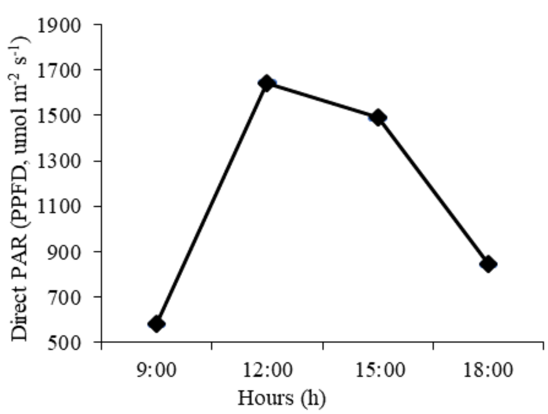

Figure 1. Direct PAR of the Murta orchard measured at different times of the day. Source: Own preparation

Physiological characteristics and vegetative growth of murta

At the same time as photosynthetic photon flux density measurements, stomatal conductance measurements (Gs, mmol m^{-2} s^{-1}) were performed in the study. For this, a portable porometer model SC-1 (Decagon Devices INC, Washington, DC, USA) was used. The Gs measurements were performed on fully illuminated leaves of the same plant, shoots, location, and frequencies used in the chlorophyll fluorescence measurements (Retamal-Salgado et al., 2017). To evaluate the effects of compost on plant physiology, it was measured the maximum intensity of fluorescence (Fm) and the minimum intensity of fluorescence (Fo) of chlorophyll. Both Fo and Fm were determined after a period of 30 min in which the leaves were adapted to darkness using foliar clips. With these parameters, the maximum photochemical efficiency of photosystem II (Fv/Fm) was quantified using the following relationship proposed by Van Kooten & Snel (1990). This was done using a portable fluorimeter model OS-5p (Opti-Sciences, Hudson, NH, USA) during a clear day at four times of the day, respectively: 09:00, 12:00, 15:00, and 18:00, on leaves exposed to the sun (Pinto-Poblete et al., 2022).

Additionally, a characterization of pigments was carried out in the experiment. The SPAD (Soil Plant Analysis Development) index was measured on leaves at midday with the criteria used for chlorophyll fluorescence and Gs measurements, after harvest. The data were obtained through a portable chlorophyll meter (MC-100, Apogee Instruments, Logan, UT, USA) equipment that determines a value proportional to the amount of chlorophyll present in the leaf (da Cunha et al., 2015). The flavonoid and anthocyanin content of the leaves was measured at noon with the criteria of the previous parameters, through the fluorescence ratio at the wavelengths F 660 nm / F 325 and F 660 nm / F 525 nm respectively. For the content of flavonoid and anthocyanin in leaf, was used a multi-pigment portable equipment model MPM-100 (Opti-Sciences, Hudson, NH, USA).

In December 2022, the height of the murta plant from the base (cm) and the length of the shoot were measured, averaging the total number of shoots on the plant. A single measurement was performed at 12:00 h.

Statistical analysis

The data were subjected to analysis of variance (ANOVA) with a significance level of $p < 0.05$. Comparison of means was performed using Fisher's least significant difference (LSD) test. The experimental design considered four compost treatments, with four replicates per treatment and two experimental units per replicate, resulting in eight experimental units per treatment. The experimental units were used as the basis for treatment comparison. Principal component analysis (PCA) was performed using mean-centered data based on eigenvalues to determine the correlation and discrimination between soil and plant variables under different doses of compost using R software (Kahle & Wickham, 2013).

Results

This study evaluated the effects of compost dose on soil fertility parameters, plant physiological and morphological development, and foliar pigments in murta plants. Compost application significantly affected available nitrogen, Olsen phosphorus, available potassium, and soil organic matter. At the plant level, compost dose modified stomatal conductance, maximum quantum yield of photosystem II, plant height, shoot length, and foliar pigment content. Overall, the 10 t ha^{-1} treatment showed the strongest response in available nitrogen, available potassium, stomatal conductance, and anthocyanin content, whereas the 15 t ha^{-1} treatment increased soil organic matter, plant height, and shoot length.

Effect of compost on soil fertility

Regarding soil chemical parameters, compost application significantly affected available nitrogen, available potassium, organic matter, and Olsen phosphorus (Table 3). The 10 t ha^{-1} treatment showed the highest available nitrogen content, with increases of 28.1%, 56.8%, and 48.5% compared with the 0, 5, and 15 t ha^{-1} treatments, respectively. In addition, the 10 t ha^{-1} treatment presented 41.6% higher available potassium than the 15 t ha^{-1} treatment. Soil organic matter increased significantly under the 15 t ha^{-1} treatment compared with the other treatments. Olsen phosphorus was higher in the control treatment than in the 10 and 15 t ha^{-1} treatments, while the 5 t ha^{-1} treatment did not differ significantly from the other treatments. Compost doses did not significantly affect soil pH, which showed an average value of 6.15.

Table 3. Chemical analysis of the soil during the 2022 season. Different lowercase letters indicate significant differences according to Fisher's LSD test ($p < 0.05$). Values correspond to mean ± standard error, considering eight experimental units per treatment. 0: control treatment without compost application; 5: 5 t ha^{-1} treatment; 10: 10 t ha^{-1} treatment; 15: 15 t ha^{-1} treatment. All samples were obtained at the end of the study in April 2023 at a depth of 0–30 cm.

Parameter	Treatments (t ha^{-1})				Anova p values
	0	5	10	15	
Available nitrogen (mg kg^{-1})	73.9 ± 15.9 b	44.4 ± 4.6 b	102.8 ± 27.1 a	52.9 ± 16.1 b	0.041
Olsen Phosphorus (mg kg^{-1})	16.5 ± 0.03 a	14.1 ± 1.5 ab	12.3 ± 0.4 b	10.3 ± 0.1 b	0.049
Available potassium (mg kg^{-1})	263.9 ± 32.3 a	191.1 ± 3.2 ab	217.3 ± 18.5 a	126.7 ± 10.2 b	0.038
Organic matter	10.2 ± 0.3 b	11.05 ± 0.2 b	11.2 ± 0.13 b	12.8 ± 0.3 a	0.006
pH	5.9 ± 0.1	5.9 ± 0.02 a	5.7 ± 0.1	6.15 ± 0.1 a	0.2337

Source: Own preparation

Effect of compost on physiology, vegetative growth and plant pigments

Stomatal conductance was affected by compost dose, with the 10 t ha^{-1} treatment showing higher values at 12:00 h and 18:00 h compared with the other treatments (Figure 2a). In contrast, the 15 t ha^{-1} treatment showed a lower stomatal conductance response during these measurement times. The maximum quantum yield of photosystem II also varied among treatments (Figure 2b). At 09:00 h, the 5 t ha^{-1} treatment showed higher Fv/Fm values than the control treatment.

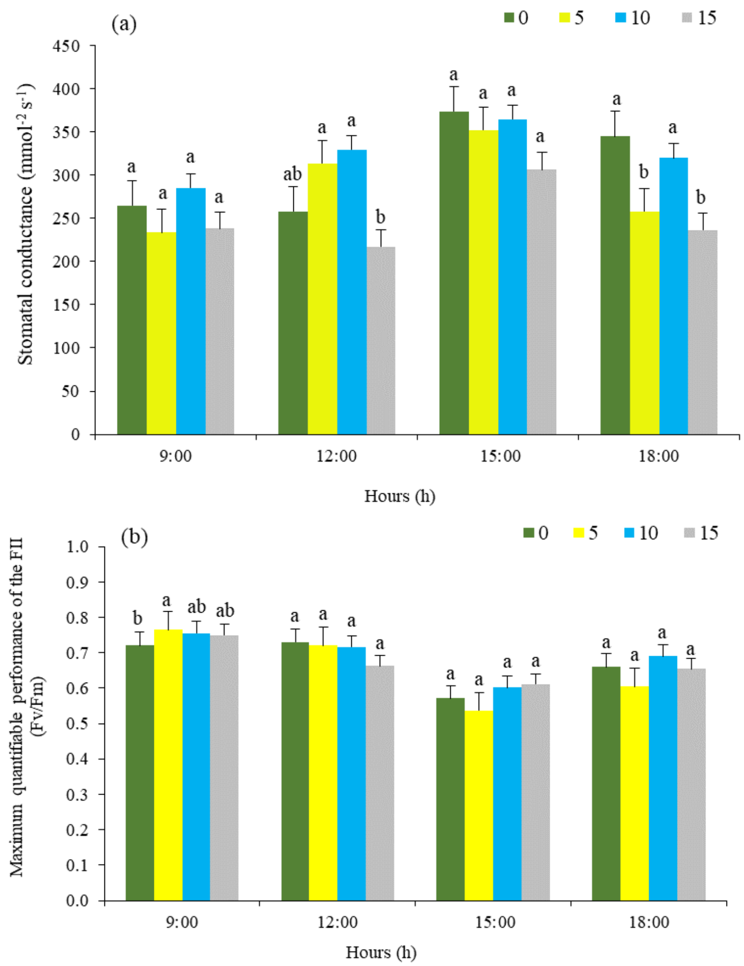

Figure 2. Effect of different doses of compost on (a) stomatal conductance (mmol m^{-2} s^{-1}) and (b) maximum quantum yield of photosystem II (Fv/Fm) in murta leaves during the 2022–2023 season. Different lowercase letters indicate significant differences according to Fisher's LSD test ($p < 0.05$). Values correspond to mean ± standard error considering eight experimental units per treatment. The bars correspond to the experimental error for each treatment. 0: control treatment without compost application; 5: 5 t ha^{-1} treatment; 10: 10 t ha^{-1} treatment; 15: 15 t ha^{-1} treatment.

The 15 t ha^{-1} treatment generated the highest plant height, reaching 75.53 cm, compared with the control treatment, which reached 64.31 cm (Figure 3a). The 5 and 10 t ha^{-1} treatments did not differ significantly from the other treatments for this parameter. Branch length was also affected by compost dose (Figure 3b).

The 15 t ha^{-1} treatment showed the highest branch length, with 18.07 cm, compared with the 0 and 5 t ha^{-1} treatments, which did not differ from each other and presented an average value of 12.8 cm. The 10 t ha^{-1} treatment reached 13.9 cm and did not differ significantly from the other treatments.

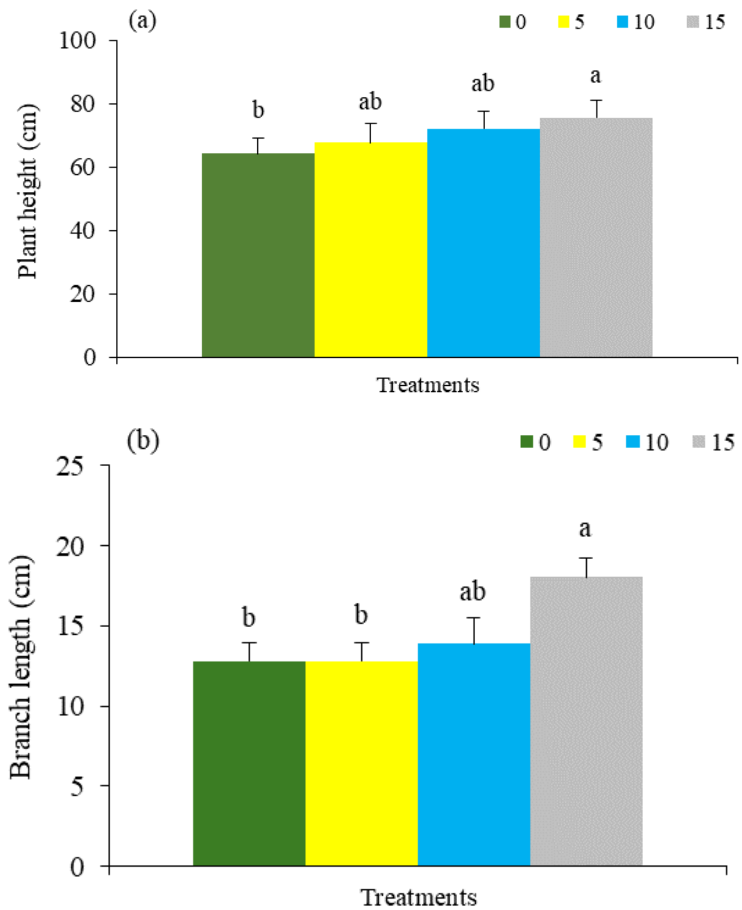

Figure 3. Effect of different doses of compost on vegetative growth variables: (a) plant height (cm) and (b) shoot length (cm). Different lowercase letters indicate significant differences according to Fisher's LSD test ($p < 0.05$). Values correspond to mean ± standard error considering eight experimental units per treatment. The bars correspond to the experimental error for each treatment. 0: control treatment without compost application; 5: 5 t ha^{-1} treatment; 10: 10 t ha^{-1} treatment; 15: 15 t ha^{-1} treatment.

Regarding chlorophyll content, no statistically significant differences were observed among compost doses, including the control treatment (Figure 4a). Flavonoid content decreased significantly under the 15 t ha^{-1} treatment compared with the other compost doses (Figure 4b). In contrast, anthocyanin content was significantly higher under the 10 t ha^{-1} treatment, increasing by 37.5% and 34.8% compared with the 5 and 15 t ha^{-1} treatments, respectively (Figure 4c).

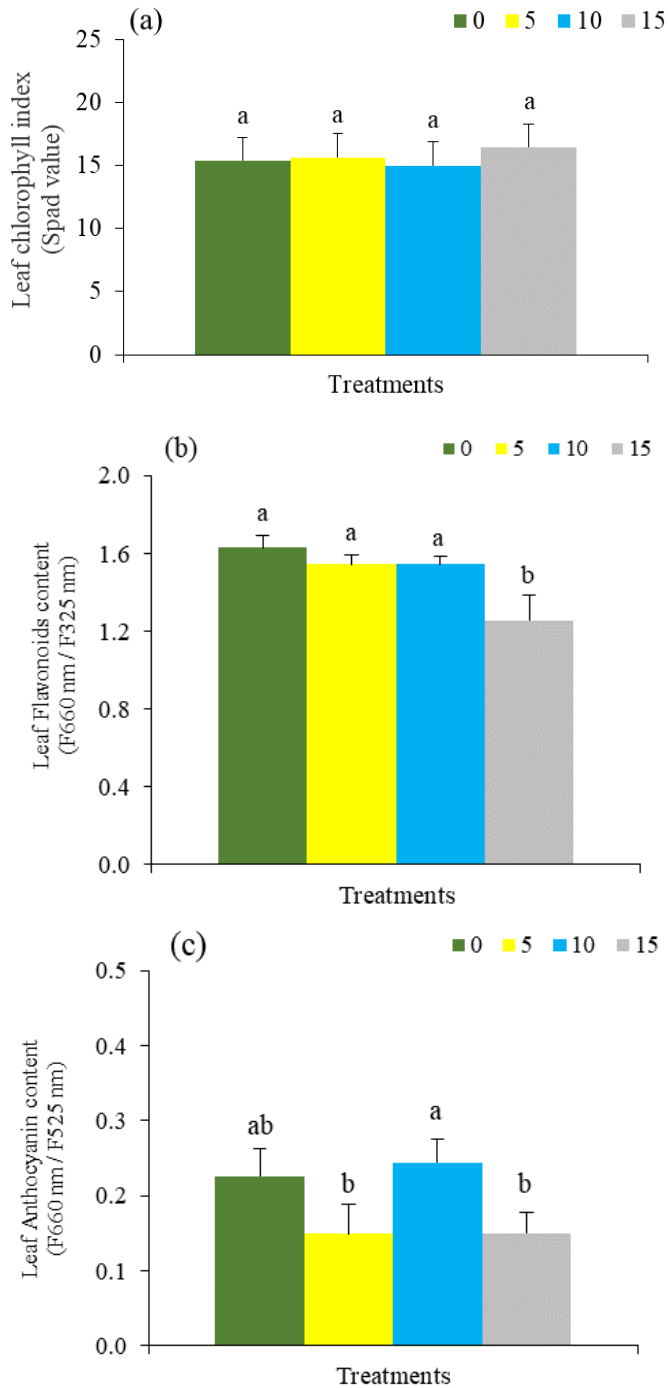

Figure 4. Effect of different doses of compost on (a) chlorophyll index, (b) flavonoid content (F660 nm / F325 nm), and (c) anthocyanin content (F660 nm / F525 nm) in murta leaves during the 2022-2023 season. Different lowercase letters indicate significant differences according to Fisher's LSD test ($p < 0.05$). Values correspond to mean ± standard error considering eight experimental units per treatment. The bars correspond to the experimental error for each treatment. 0: control treatment without compost application; 5: 5 t ha^{-1} treatment; 10: 10 t ha^{-1} treatment; 15: 15 t ha^{-1} treatment.

Soil-plant interaction

The correlation matrix (Figure 5) indicated highly significant correlations between soil nutrients N and K and soil pH (＞-0.69). Similarly, soil P and K were highly related to soil OM (＞-0.75). Plant height and shoot length were moderately correlated with soil P (＞-0.53).

Principal component analysis (PCA) (Figure 6a) was performed for the 11 parameters. The main components, PC1 and PC2, were retained at 30.85% and 26.36%, respectively. This represents all the parameters as vectors in the biplot graph, whereas the length of the vector shows how well the variables are represented in this graph. The treatments in the PCA (Figure 6b) were represented by numbers 1-3 for 0 t ha^{-1}; 4-6 for 5 t ha^{-1}; 7-9 for 10 t ha^{-1}; and 10-12 for 15 t ha^{-1}.

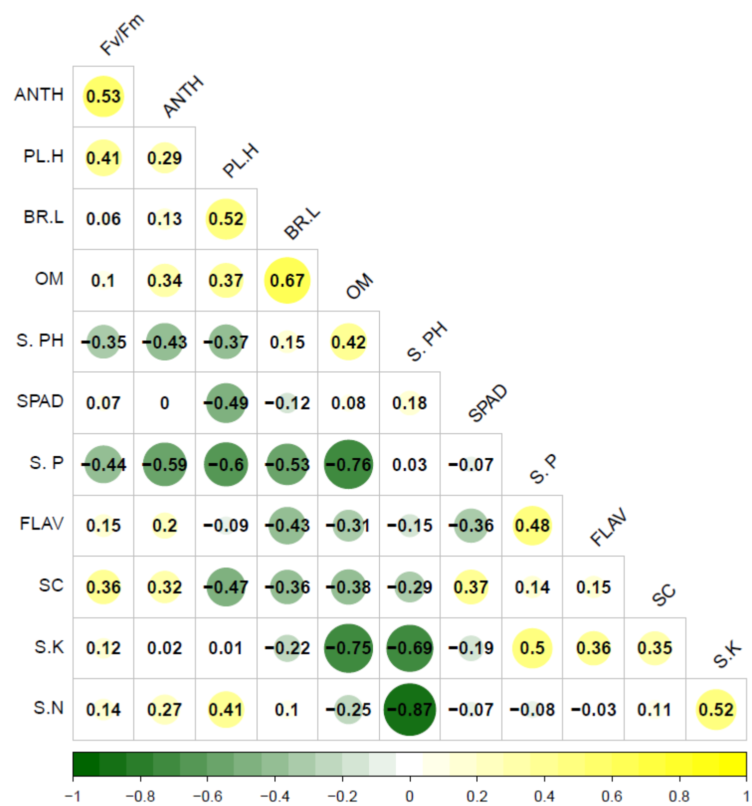

Figure 5. Correlation matrix between soil and plant chemical parameters. Anthocyanins (ANTH), plant height (Pl.H), shoot length (Br. L), organic matter (OM), soil pH (S.pH), chlorophyll index (SPAD), soil phosphorus (S.P), flavonoids (FLAV), stomatal conductance (SC), soil potassium (S.K) and soil nitrogen (S.N). Number indicates Pearson coefficient.

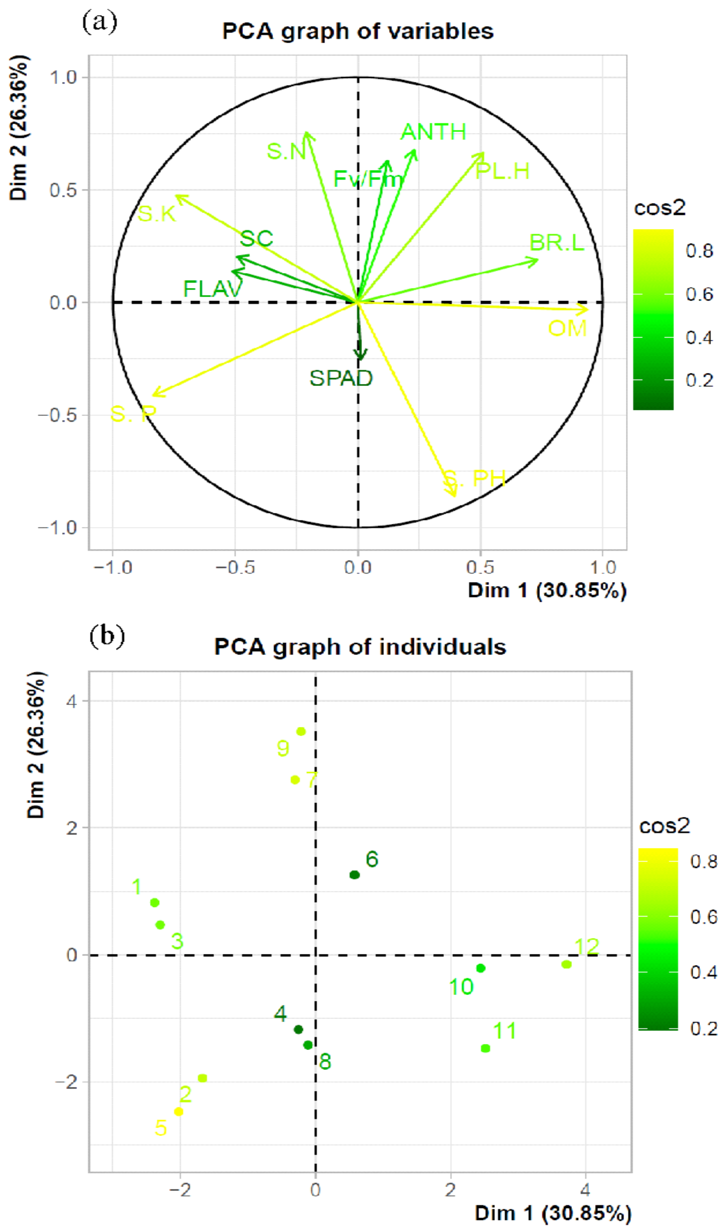

Figure 6. Principal component analysis (PCA). Anthocyanins (ANTH), plant height (Pl.H), shoot length (Br. L), Organic matter (OM), soil pH (S.pH), chlorophyll index (SPAD), soil phosphorus (S.P), flavonoids (FLAV), stomatal conductance (SC), soil potassium (S.K) and soil nitrogen (S.N). (a) PCA of variables; (b) PCA of individuals.

Discussion

The results agree with the proposed hypothesis that organic fertilization, by increasing organic matter and improving soil physicochemical properties, can promote vegetative plant growth (García-Orenes et al., 2016; Li et al., 2023). However, the response was not linear across compost doses, suggesting that murta may present an optimal range of organic fertilization beyond which physiological and biochemical benefits are not necessarily enhanced. However, the highest compost dose decreased foliar pigments, such as flavonoids and anthocyanins, which is consistent with Kong & Nemali (2021), who reported that increased vegetative growth may occur at the expense of foliar pigment accumulation. This trade-off suggests a possible allocation shift from secondary metabolism toward vegetative growth when nutrient availability and organic inputs are high.

These findings indicate that organic fertilization generates soil-level benefits that influence plant development, which is relevant for the establishment of future orchards of native species such as murta. The improvement in soil fertility agrees with previous studies showing that increasing compost doses can enhance nutrient and organic matter availability (Pinto-Morales et al., 2022; Lyzenga et al., 2023). This higher fertility may support the activity of soil microorganisms, such as bacteria and fungi, which are capable of synthesizing enzymes involved in carbon, nitrogen, and phosphorus transformations, including ureases, proteases, esterases, and phosphatases (Taylor et al., 1989; Zhang et al., 2005). Nevertheless, the greater organic matter content observed under the highest compost dose may indicate slower decomposition during the short experimental period of eight months (Fischer et al., 2020). In addition, the lower nitrogen and potassium contents at the highest dose could be explained by greater plant growth and, consequently, higher nutrient extraction by plants (Betancur et al., 2024). The slight variation in soil pH may be associated with the high buffering capacity of Andisol soils, which tend to resist changes in soil acidity or alkalinity (Ng et al., 2022; Pinochet et al., 2005).

The increase in stomatal conductance under 10 t ha^{-1} suggests improved physiological conditions, including gas exchange and photosynthetic performance, particularly during periods of high radiation (Liu et al., 2023b). From a mechanistic perspective, higher stomatal conductance may facilitate CO_2 diffusion into the leaf, supporting carbon assimilation when radiation is not limiting. This response is especially relevant in murta because gas exchange traits are sensitive to light conditions and can influence plant performance under orchard management. This response may be related to the higher contribution of soil nutrients, such as nitrogen, through compost application, which can improve plant physiological status and growth, as reported in Arabidopsis thaliana after exposure to compost (Miyamoto et al., 2023). Conversely, the lower stomatal conductance response under 15 t ha^{-1} suggests greater stomatal closure. Similar effects have been observed when high doses of organic material were applied, reducing stomatal conductance and CO_2 assimilation in Brassica juncea L. (Batista-Silva et al., 2019). Therefore, excessive compost application may generate an imbalance between vegetative demand, nutrient availability, and plant water regulation, reducing the efficiency of gas exchange despite improving some growth variables.

The improvement in the maximum quantum yield of photosystem II under compost application is consistent with findings in tomato plants, where organic compounds based on animal manure improved plant physiology, chlorophyll fluorescence, shoot development, and leaf tissue hydration (Aydi et al., 2023). These responses suggest improved photosynthetic efficiency (Brestic & Živčák, 2013). In relation to vegetative growth, the response observed in murta highlights the importance of defining appropriate compost doses to obtain significant growth responses in this species (Rady et al., 2016). The increase in shoot length under compost application agrees with Zuo et al. (2018), who reported increased strawberry plant growth after compost application. Since soil nutrients did not vary markedly between 10 and 15 t ha^{-1} at the end of the study, the greater vegetative growth under the highest dose may be associated with physical or biological improvements derived from organic matter inputs, including soil structure, stable aggregate formation, microbial biomass, water infiltration, and improved conditions for plant development (Sainju et al., 2022). Therefore, future studies should consider soil physical and biological variables because of their potential role in murta growth.

The absence of significant differences in chlorophyll content contrasts with previous reports showing that similar compost doses increased chlorophyll content in wheat and pineapple plants (García-Mendívil et al., 2014; Liu et al., 2013). This response could be attributed to the adequate initial fertility of the soil, with high nitrogen, phosphorus, and potassium values, which may have attenuated the effect of compost application on chlorophyll synthesis (Yadav & Garg, 2015). Although compost application can increase flavonoid content in plants, high doses similar to those used in this study may reduce this pigment (Alromian, 2020; Sarwar et al., 2020). Since flavonoids play an antioxidant role under stress conditions (Shomali et al., 2022), the reduction observed under 15 t ha^{-1} may indicate a lower investment in stress-related secondary metabolism. This response may also reflect a dilution effect associated with increased vegetative growth, where the expansion of plant tissues reduces the relative concentration of phenolic compounds. The decrease in anthocyanin content under 15 t ha^{-1} agrees with results reported in grapevines, where 20 t ha^{-1} of compost reduced anthocyanin content compared with a lower dose of 10 t ha^{-1} (Cataldo et al., 2023).

However, the greater anthocyanin response under 10 t ha^{-1} may be explained by higher soil nitrogen and potassium concentrations, as these nutrients are involved in the synthesis of this pigment (Papafotiou et al., 2007). Therefore, 10 t ha^{-1} may represent a more balanced dose, capable of improving physiological performance without reducing the accumulation of bioactive pigments. Overall, foliar pigments responded differently to compost dose, with flavonoids and anthocyanins being reduced under 15 t ha^{-1}. This is relevant because flavonoids are phenolic compounds with health-promoting properties, including antioxidant, anti-inflammatory, and antibacterial effects (Hollman & Katan, 1999). Thus, compost application may influence the synthesis of foliar pigments in murta, providing an additional functional perspective beyond fruit consumption, although this aspect was not directly evaluated in the present study. Considering that murta leaves and fruits are recognized for their bioactive compounds, maintaining pigment accumulation is agronomically relevant not only for plant physiology but also for the potential functional value of the crop.

The relationships observed in the correlation matrix and principal component analysis support the links among soil nutrients, pH, organic matter, and plant growth. The associations between nitrogen, potassium, and pH may be related to nutrient uptake and the release of hydrogen ions by roots, which can modify soil pH and affect nutrient availability (Youssef et al., 2023). Likewise, organic matter decomposition and mineralization can generate organic acids that contribute to soil pH variation (Jain & Kalamdhad, 2020). The negative relationship between soil phosphorus, potassium, and organic matter may reflect nutrient release during microbial mineralization processes (Feng et al., 2021), whereas the negative association between soil potassium and vegetative growth variables may be associated with greater potassium extraction by plants during growth (Betancur et al., 2023). However, the moderate variance explained by the first two principal components indicates that soil-plant relationships in murta should be interpreted cautiously and require further study. This represents a limitation of the study, together with the short evaluation period and the low number of experimental replicates, which restrict the generalization of the results.

Future studies should include longer monitoring periods, higher sample sizes, soil biological indicators, fruit yield, and fruit quality variables to better define compost recommendations for murta orchards. From a productive perspective, the results suggest that moderate compost application could be incorporated into agroecological management strategies for murta, whereas excessive doses should be evaluated carefully because they may favor vegetative growth at the expense of physiological efficiency and bioactive pigment accumulation.

Conclusions

Our results showed that the application of compost at various doses to the soil had a notable influence on the chemical quality of the soil and physiological development of murta plants. A dose of 15 t ha^{-1} resulted in higher soil OM content and plant growth, as evidenced by the increase in the height and length of the branches. However, 15 t ha^{-1} decreased foliar pigments such as flavonoids and anthocyanins. Treatment with 10 t ha^{-1} resulted in significant improvements in the soil N content, plant stomatal conductance, and foliar anthocyanin content. These benefits contribute to the well-being of plants by controlling stress and have potential beneficial applications for humans. Economic resources were also optimized when applying a dose of 10 t ha^{-1} compared to higher doses. Therefore, a rate of 10 t ha^{-1} is recommended for fertilizing murta. However, questions remain regarding the productive behavior of murta in response to compost dosage. Future research should address how different doses of compost can influence the productivity and nutraceutical properties of murta. To our knowledge, this is the first study to clarify the effects of organic fertilization on cultivated murta.

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Disclaimers

All authors made significant contributions to the document, agree with its publication and declare that there are no conflicts of interest in this study.

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