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Effects of Paclobutrazol and Mepiquat Chloride on the Physiological, Nutritional, and Morphological Behavior of Potted Icterina Sage under Greenhouse Conditions

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Abstract: Plant growth regulators (PGRs) are commonly used in horticulture to improve crop quality, save water, and enhance plant resilience to stress. In this study, we examined the effects of two PGRs, paclobutrazol (PBZ) and mepiquat chloride (MC), on the growth and health of *Salvia officinalis* 'Icterina', a popular ornamental and aromatic plant. Parameters such as growth and development, water status, chlorophyll levels, nutrient content, photosynthetic performance, and gas exchange were evaluated. The study took place in a greenhouse with automatic watering and three plant groups: one treated with PBZ, another with MC, and a control group (untreated). Only one application of growth retardants was made, with 0.1 L per pot of a 100 mg/L solution of PBZ, and 0.1 L per pot of a 2.5 g/L solution of MC. The results showed that both PBZ and MC treatments reduced the plant's water consumption, with PBZ being more effective in limiting leaf growth and promoting the accumulation of substances in the leaves. Both PGRs resulted in smaller plants, reducing the need for soil and potting materials. The MC treatment improved nutrient absorption, reducing the requirement for fertilizers. When subjected to environmental stress from March to June in the greenhouse, Salvia plants benefited from the application of both PGRs, as they helped maintain photosynthetic activity. These findings contribute to improving the sustainability of nursery practices by utilizing PGRs to conserve resources and mitigate the impact of stressful environmental conditions on sage plants.

Keywords: growth retardants; water consumption; photosynthesis; Salvia; potted plant

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Citation: Bañón, D.; Ortuño, M.F.; Sánchez-Blanco, M.J.; Pagán, B.L.; Bañón, S. Effects of Paclobutrazol and Mepiquat Chloride on the Physiological, Nutritional, and Morphological Behavior of Potted Icterina Sage under Greenhouse Conditions. *Agronomy* **2023**, *13*, 2161. https://doi.org/10.3390/agronomy13082161

Academic Editor: Othmane Merah

Received: 9 June 2023
Revised: 7 August 2023
Accepted: 16 August 2023
Published: 17 August 2023

1. Introduction

Plant growth regulators (PGRs) are synthetic or naturally occurring chemicals that are widely utilized in nursery and horticulture practices. These substances modify the hormonal balance and growth patterns of crops, resulting in numerous benefits such as an enhanced crop quality, improved physiological traits, and an increased tolerance to abiotic stress [1]. In potted plant production, the most used PGRs are growth retardants, which act as inhibitors of gibberellin biosynthesis. Their primary application is to reduce longitudinal shoot growth, leading to more compact and smaller plants with greener leaves. Additionally, the use of retardants helps to increase plant tolerance to temperature fluctuations, drought, and salinity [2]. Another advantage of employing retardants in nurseries is the assurance that the size of the plant matches the size of the pot, while also improving the water and nutritional status of the plants [3].

Paclobutrazol (PBZ) and mepiquat chloride (MC) belong to a group of growth retardants that are frequently used to inhibit plant growth, interfering with gibberellin biosynthesis. MC inhibits the early stages while PBZ inhibits the later stages of gibberellin biosynthesis [4]. Many ornamental plants have benefited from the utilization of PBZ [5], such as sunflowers [6] and sequoia seedlings [7]. PBZ helps plants better withstand stress conditions by maintaining relative water content (RWC), membrane stability, leaf photosynthesis rate, levels of photosynthetic pigments, chloroplast ultrastructure, and protects the photosynthetic apparatus [8,9].

MC is a phytoregulator commonly used to reduce vegetative growth on cotton and, as a result, to increase yield and improve fiber quality [10]. MC is also used to inhibit sprouting in onions and garlic and, in combination with other phytoregulators, it helps to prevent lodging in cereals and grass seed crops [11]. However, MC has been used less in floriculture, which highlights the need for studies in this regard. In addition to reducing plant growth, MC can improve leaf CO_2 exchange rate, transpiration, stomatal conductance, and chlorophyll content, which protects plants against stresses [12].

Salvia officinalis (sage) is an ornamental and aromatic plant that belongs to the *Lamiaceae* family that is widely used in gardening, cooking, cosmetic, and pharmaceutical industries. *Salvia officinalis* "Icterina" is a cultivar of the common sage, grown mainly for its ornamental qualities, although it is also used for medicinal purposes. Gardeners appreciate the cultivar's leaves, which have a green color with a wide golden border and emit a faint pleasant aroma [13].

The effects of PGRs on the growth and phytochemical properties of sage have been explored in several studies. For instance, a study by Singh et al. [14] found that PBZ application significantly increased the oil content and ornamental quality. However, the effects of growth retardants on the development and physiology of Icterina sage remain unclear due to the limited information available. The knowledge about such effects will contribute to our understanding of the potential use of PGRs in the nursery production of Icterina sage. Therefore, this work aims to assess the effects of PBZ and MC on water consumption, relative water content, growth, plant size, chlorophyll content, nutrient content, gas exchange, and photosystem II of Icterina sage under greenhouse conditions.

2. Materials and Methods

2.1. Plant Material and Cultivation Parameters

The experiment took place on the premises of Cartagena's Polytechnic University farm (37° 35′ N, 0° 59′ W), inside a semicircular polycarbonate greenhouse (15 m long × 8 m wide, 3.5 m high on the sides and 5.5 m high in the center). Seedlings of *Salvia officinalis* "Icterina" (Viveros Bermejo S.L., Totana, Spain) (6–7 cm in height and 6–8 leaves) were transplanted into 2.5 L black plastic pots (Viveros Bermejo S.L., Totana, Spain) (15 cm in height and 17 cm in width) on 17 December 2021. The pots were arranged on metal grow tables (3 × 1.25 m^2). The substrate used was a commercial product (Universal Fertiberia) composed of a mixture of peat, coconut fiber, and perlite (67/30/3, *v*/*v*/*v*) (Fertiberia S.A., Madrid, Spain). Its maximum water-holding capacity is 63.2% of the pot volume. Hourly recordings of temperature and relative humidity were recorded using a LOG 32 TH data logger (Dostmann electronic GmbH. Wertheim-Reicholzheim, Germany). The vapor pressure deficit (VPD) was estimated using the mathematical equation of Snyder et al. [15]. The data of daily maximum temperatures and average VPD after the application of the PGRs are shown in Figure 1.

2.2. Automated Irrigation System and Soil Moisture Sensors

Each pot was equipped with two self-compensating and anti-drainage emitters (Netafim Ltd., Hatzerim, Israel), with a flow rate of 2 L h^{-1} each. Water was delivered to the plants through a 4 mm diameter, 50 cm long tube that terminated in a plastic arrow, which was inserted into the substrate. The irrigation management relied on GS3 soil moisture sensors (METER Group Inc., Pullman, WA, USA) that were placed between two emitters in the east-facing quadrant of the root ball. One sensor was randomly installed in three pots for each treatment.

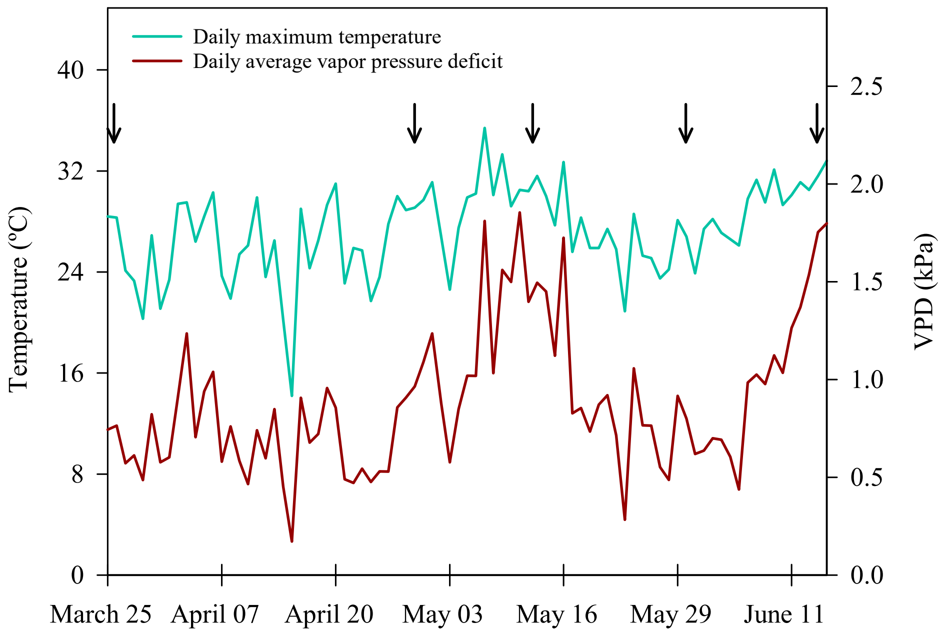

Figure 1. Evolution of daily maximum air temperature (°C) and daily mean vapor pressure deficit (VPD, kPa) from 25 March 2022 to 15 June 2022. The arrows indicate the days on which foliar gas exchange parameters were measured (25 March, 29 April, 13 May, 31 May, and 15 June).

The sensors were connected to a CR1000 data logger (Campbell Scientific, Ltd., Logan, UT, USA) via a multiplexer (Campbell Scientific, Ltd., Logan, UT, USA). To control the irrigation of each treatment, three solenoid valves were used and controlled through an SMD-CD16D multicontrol port multiplier (Campbell Scientific Ltd., Logan, UT, USA). Each treatment used a 1000 L irrigation tank to store the irrigation water. A waterproof box located at the greenhouse's center contained the electronic system. In the event of a power failure, a charger and a 12 V battery were included to guarantee ongoing system functionality.

The VWC was derived using a calibration equation tailored to the substrate used in this experiment (VWC = $-0.047 \times$ permittivity^2 + $3.154 \times$ permittivity + 7.740; $r^2 = 0.92$) developed by Valdés et al. [16]. The moisture level was checked by the data logger every hour, and compared to a target level of 44% VWC. When the moisture was below that threshold, a 1 min irrigation was applied to avoid leaching.

The nutrient solution was formulated by incorporating a commercially available fertilizer containing a nutrient ratio of 4-1.7-4.5-4-1.4 ($N/P_2O_5/K_2O/CaO/MgO$) to the irrigation water at a concentration equivalent to the 0.5 dS m^{-1} rise. The pH of the three irrigation solutions was set to 6.7 using nitric acid, and the final electrical conductivity (EC) of the water and fertilizer mixture was 1.8 dS m^{-1}.

2.3. Water Usage and Water Use Efficiency

The total amount of water used was calculated by multiplying the number of irrigation events by the amount of water used in each irrigation during the whole experiment. The total water applied corresponded to water consumption only as there was no leaching. Water use efficiency (WUE) was determined by dividing the plant dry weight produced from the start to the end of the experiment by the amount of water used during that time.

2.4. Plant Growth Regulator Treatments

The experiment involved three groups: one treated with PBZ, another treated with MC, and a control group (not treated). In each group, there were 20 plants, and every plant had its dedicated pot. For the PBZ treatment, we added 0.1 L per pot of a solution with a concentration of 100 mg/L (equivalent to 10 mg of active ingredient). For the MC treatment, we applied 0.1 L per pot of a 2.5 g/L solution of MC (equivalent to 250 mg of active ingredient). These solutions were prepared by diluting in water the commercial products Cultar® (250 g/L paclobutrazol) and Pix® (50 g/L mepiquat chloride). The growth retardant solutions were applied directly onto the substrate once on 25 February 2022. The measurements started a month later, on 25 March, and continued until 15 June.

2.5. Plant Growth and Chlorophyll Content

At the end of the experiment, a size index was measured on ten plants per treatment, calculated as (plant width A + plant width B + plant height)/3. Plant width A was measured at the widest part of the plant, and a second measurement was taken perpendicularly (plant width B). Plant height was measured from the base of the plant at the substrate surface to the most apical growth. Then, we counted the number of leaves per plant and determined the blade area. The leaf area was determined by multiplying the area of each blade by the total number of leaves. Finally, we dried the leaves, shoots, and roots of these plants in a convection oven at 65 °C for four days to achieve total moisture loss. We weighed each plant using a precision analytical balance (Mod. TE2145, Sartorius Weighing Technology, GmBH, Goettingen, Germany).

To measure the chlorophyll content in the leaves, we followed a method that involved dissolving 50 mg of fresh leaf in 5 mL of N, N-dimethylformamide. The solution was stirred for one day at 4 °C in the dark, after which we used an Uvikon 940 spectrophotometer (Kontron Instruments AG, Zürich, Switzerland) to measure the absorbance of the resulting extract at 647 nm and 664 nm, which allowed us to determine the amount of chlorophyll-a and chlorophyll-b, respectively. To determine the actual chlorophyll concentrations (mg gFW^{-1}), we used the equations described by Inskeep and Bloom [17].

2.6. Mineral Ion Content in Plant Tissues

After the experimental period, we analyzed the mineral ion content in leaves, shoots, and roots across six pots for each treatment. To accomplish this, we first oven-dried the plant tissues and then ground them into a fine, dry powder. We used inductively coupled plasma emission spectrophotometry (IRIS Intrepid II XDL ICP-OES, Thermo Fischer Scientific, Waltham, MA, USA) to determine the levels of inorganic elements (K^+, P, Ca^{2+}, Na^+, and Mg^{2+}). The chloride concentration in plant tissues was determined by analyzing the aqueous extract using a chloride analyzer (Model 926, Sherwood Scientific, Cambridge, UK), while the NO^{3-} concentration was determined using a 850 ProfIC AnCat-MCS dual-channel ion chromatograph (Metrohm AG, Herisau, Switzerland).

To extract the plant tissues, we mixed 100 mg of dry powder with 40 mL of deionized water and stirred the mixture for 30 min on a rotary shaker at 30 rpm. We then filtered the mixture through a 0.45 µm PTFE syringe filter and analyzed the chloride concentration in the aqueous extract using a chloride analyzer (Mod. 926, Sherwood Scientific, Cambridge, UK).

2.7. Stomatal Conductance and Photosynthesis

We used a portable gas exchange meter (LI-COR 6400, LI-COR Inc., Lincoln, NE, USA) to measure stomatal conductance (g_s) and net photosynthetic rate (P_n) in six randomly chosen plants for each treatment following a procedure outlined in [18]. We conducted five measurements throughout the experimental period, on the following dates: 25 March, 29 April, 13 May, 31 May, and 15 June (see Figure 1).

2.8. Chlorophyll Fluorescence

An FMS-2 pulse-modulated fluorimeter was used to measure the fluorescence of chlorophyll at the end of the experiment (Gomensoro Scientific Instrumentation, S.A., Madrid, Spain) following the method described by Miralles et al. [19]. The following parameters of fluorescence were measured: (i) the maximum photochemical efficiency of photosystem II (PSII) (Fv/Fm), (ii) effective quantum yield (ϕPSII), and (iii) non-photochemical quenching (NPQ).

2.9. Statistical Analysis

A simple analysis of variance (ANOVA) was performed using Statgraphics Centurion software (v.XVI, StatPoint Technologies, Inc., Warrenton, VA, USA) to determine the statistical differences between treatments. The means were separated by the least significant difference (LSD) test at a probability level of less than 0.05 if ANOVA showed significant effects.

3. Results and Discussion

3.1. Growth, Water Consumption, and Leaf Chlorophyll

The two PGRs used in the study caused significant changes in plant growth (Table 1). PBZ significantly reduced plant dry weight by 55%, while MC caused a smaller 19% decrease compared to the control. This effect has been observed in other ornamental crops, such as lantana [20] and chrysanthemum [21]. Compared to MC, PBZ demonstrates stronger growth restriction capabilities, likely due to its extended duration of action and its better ability to inhibit gibberellin biosynthesis than MC. PBZ's enhanced capacity to hinder gibberellin production could stem from its ability to block three specific steps in the terpenoid pathway, which is responsible for the synthesis of gibberellins [1].

Table 1. Growth parameters of Icterina sage plants treated with mepiquat chloride (MC) and paclobutrazol (PBZ) and non-treated (control) at the end of the experiment.

Parameters	Treatments		
	Control	Mepiquat	Paclobutrazol
Plant dry weight (g)	21.98 c	17.8 b	9.7 a
Aerial dry weight (g)	15.7 c	11.79 b	4.89 a
Root dry weight (g)	6.28 b	6.01 b	4.81 a
Shoot-to-root ratio	2.5 c	1.96 b	1.02 a
Size index (cm)	23.17 c	19.43 b	15.42 a
Leaf area (dm^2)	13.88 c	6.29 b	3.34 a
Number of leaves per plant	242 c	160 b	141 a
Blade area (cm^2)	5.74 c	3.93 b	2.37 a
Leaf chlorophyll (mg gFW^{-1})	0.88 a	1.02 b	1.18 c
Water applied (L pot^{-1})	16.1 c	12.8 b	8.05 a
Relative water content (%)	79.02 a	80.09 a	82.87 b
Water use efficiency (gDW L^{-1})	1.37 b	1.39 b	1.21 a

Statistically significant differences between means ($p < 0.05$) are indicated by different letters in the same row, according to the LSD test.

PBZ mainly affected the aboveground parts of the plant, leading to a 69% reduction compared to the control, while the reduction in root dry weight was 25% (Table 1). Trees treated with recommended dose rates of PBZ showed an average shoot growth reduction of 40 to 60 percent [22]. While the decrease in root dry weight was relatively smaller, roots affect many aspects of plants' physiology. Even small reductions in root growth could have a significant impact on the overall health of the plant.

As opposed to our data, Maghsoudi et al. [23] reported that PBZ promoted root growth in *S. officinalis*; however, it should be considered that their plants grew under water stress. Furthermore, the review carried out by Desta and Amare [1] determines that the impact of PBZ on root growth can vary depending on the dosage administered. Lower doses were found to enhance growth, which highlights the significance of optimizing the dose of PBZ as a crucial step in any initiatives aimed at improving plant quality.

The reduction in root growth observed in PBZ-treated plants may be ascribed to both the direct influence of paclobutrazol on root growth, and the indirect effect stemming from a decline in shoot growth. In most cases, however, the outcome observed in plants treated with PBZ is a reduction in the ratio of soot to root, as seen in this study with sage. The shoot-to-root ratio of sage plants decreased from 2.52 (control) to 1.02 (PBZ) due to the

PBZ effects on biomass distribution, which is in line with a prior study on PBZ-treated avocado trees [24]. In contrast, MC did not have a significant impact on root growth but led to a 25% reduction in aboveground dry weight relative to the control, resulting in a moderate decrease in the shoot-to-root ratio (Table 1). The effect of MC on the shoot-to-root ratio has been found to be inconsistent across studies. While Wu et al. [25] reported that MC promotes root development in cotton (decreasing shoot-to-root ratio), Almeida and Rosolem [26] found no effect on the shoot-to-root ratio in cotton seedlings treated with MC. Reduction in plant size by PBZ and MC was lower than in dry biomass since the size index was reduced by 17% and 33%, respectively, compared to the control (Table 1). Nurseries may find the cultivation of smaller plants a compelling strategy because, in certain species, the smaller sizes might be preferable from a commercial point of view. Likewise, this approach can save resources on materials like substrate and pots, while maximizing space efficiency by yielding more plants per unit area.

The leaf area of sage was significantly affected by the application of MC and PBZ, leading to a 55% and 76% reduction compared to the control, respectively. This reduction in leaf area was due to a decrease in both leaf number and leaf blade size (Table 1). While MC affected the number of leaves and leaf blade size proportionally, PBZ had a greater impact on leaf number (59% reduction) than on blade size (42% reduction). Overall, PGRs reduce foliar growth, although the manner to do so may vary considerably between species. Previous studies have reported reductions in leaf area by PBZ in ornamental crops such as *Catharanthus roseus* [27] and *Gladiolus* sp. [28], mainly due to a decrease in blade size. Similarly, MC has been shown to reduce blade size and leaf area in cotton [29]. In *Lantana camara*, Matsoukis et al. [30] reported a reduction in leaf area of 22% and 60% with MC and PBZ, respectively. The lower foliar reduction in lantana by the two PGRs compared to sage may be related to its woody character while sage is an herbaceous plant. In any case, reducing leaf area permits a better control of leaf transpiration rates and improves adaptation to drought climatic conditions.

Plants treated with MC and PBZ had 16% and 34% more chlorophyll in their leaves compared to the control, respectively (Table 1). PGRs can lead to higher chlorophyll levels in leaves through various processes. For example, Berova and Zlatev [31] indicated that cytokine may be involved as this hormone stimulates chlorophyll production, while Tung et al. [29] linked increasing leaf chlorophyll to the accumulation of magnesium in the leaves of PBZ-treated cotton plants. In this regard, phytol is an essential component of chlorophyll that is synthesized through the same pathway as gibberellins. Since paclobutrazol treatment inhibits gibberellin production, it redirects intermediate compounds toward the production of more phytol. This idea has been proposed to clarify why growth inhibitors such as paclobutrazol enhance the levels of chlorophyll in leaves [22]. In any case, an increase in leaf chlorophyll is typically associated with a greener appearance, which may explain why the PGRs-treated plants displayed darker leaves compared to the control.

3.2. Water Usage, Water Use Efficiency, and Relative Water Content

Plants treated with MC required 20% less water, while those treated with PBZ needed 49% less water compared to the control group (Table 1). The reduction in water consumption after PBZ treatment has been ascribed to various factors. The main factor is the decrease in transpiration surface due to a reduced leaf area. Sage plants treated with PGRs, especially PBZ, showed a noteworthy reduction in their total leaf surface area, which directly influenced their water consumption. On the other hand, PBZ elevates the concentration of abscisic acid within leaves by influencing its breakdown. Higher levels of abscisic acid foster stomatal closure, which makes compounds like PBZ effectively reduce transpiration rates and water loss [32]. The increase in leaf relative water content could arise from a combination of increased abscisic acid contents and its influence on stomatal regulation, a reduced surface area for transpiration, and structural and morphological changes in leaves that avoid moisture loss. An increase in relative water content helps prevent a decrease in water potential [1]. PBZ has been shown to improve stomatal regulation in strawberry trees, reducing the percentage of water released through stomata, which helps to maintain plant water status [33]. In our plants, the use of PBZ and MC influenced stomatal conductance (see Section 3.3).

Dry weight and water consumption data show that PBZ reduced the efficiency of water used for producing biomass (WUE) compared to the control, while MC had no significant effect (Table 1). Reducing WUE indicates that biomass reduction was higher than consumption reduction, which could be linked to the improvement of leaf water status in the PBZ-treated plants (see RWC in Table 1). By lowering stomatal conductance and transpiration rates, an augmented ABA level enhances plant RWC and WUE. Similarly, PBZ has been suggested to increase WUE in different terms, e.g., the grain yield in maize [8] and the production of tomato fruit [34].

MC did not affect the leaf RWC compared to the control, which remained close to 80%, while PBZ slightly increased RWC (Table 1). This made PBZ-treated plants have slightly higher RWC than untreated plants, improving their ability to withstand water deficit [35]. It has been reported that PBZ produces morphological and anatomical modifications in leaves, particularly in stomatal pore size and thickness of the leaf layers [36], which may affect water retention in cells. This positive effect on RWC was also reported in PBZ-treated apple trees, but only when the plants were grown under water deficit [37].

3.3. Photosynthesis and Stomatal Conductance

The stomatal conductance (g_s) of sage plants generally decreased in all treatments as the cultivation period progressed (Figure 2A), which is related to increasing VPD and temperature inside the greenhouse, with the highest values seen on 13 May and 15 June (see Figure 1). This observed reduction in g_s is usually linked to adaptive and efficient mechanisms utilized by species to control transpiration. This mechanism helps the plant cope with stressful growth conditions, particularly during periods of high transpiration. Comparing treatments, decreasing g_s was more marked in the control and PBZ plants than MC plants, except for the days with the highest evaporative demand (13 May). The control and PBZ-treated plants had similar values during the intermediate dates of the experimental period (Figure 2A).

Regarding P_n behavior, the tendency was to gradually decrease as the season progressed until reaching minimum values on 15 June (Figure 2B). This generalized fall in g_s and P_n at the end of the experiment was promoted by the environmental stress accumulated by the plants, given the sensitivity of g_s and P_n to both temperature and VPD. If we look at the differences in P_n between the treatments during the experiment, we can see that they all have similar values (Figure 2B). In this regard, Ahmad et al. [38] attributed the decrease in photosynthetic activity of PBZ-treated *Syzygium myrtifolium* plants to the reduction in total leaf area, and not directly to stomatal regulation. However, Navarro et al. [3] attributed the decrease in growth of PBZ-treated *Arbutus unedo* trees to a reduction in both leaf area and stomatal conductance, which decreased water loss by transpiration as well as photosynthetic activity.

From 25 March to 31 May (increasing temperature and VPD, see Figure 1), the intrinsic water use efficiency (P_n/g_s) in sage plants gradually increased (Figure 2C). This suggests that they were able to use less water while still producing the same amount of biomass through photosynthesis. The same response was found from 31 May to 15 June. It suggests two physiological behaviors: (i) sage is able to develop adaptation mechanisms for maintaining its growth under stressful environments, and (ii) the plant can regulate its stomatal conductance to minimize water loss without significantly compromising photosynthesis.

At the end of the experiment, P_n values in plants treated with MC and PBZ were slightly greater than in control plants (Figure 2A). This suggests that both retardants may have helped maintain the photosynthetic activity of sage under stressful ambient conditions [39]. The physiological explanations of the protective effect of both PGRs on P_n remain controversial based on previous studies [40,41]. In this sense, it has been indicated in cotton that MC reduced P_n despite increasing leaf chlorophyll [10], while in the case of PBZ, an increased leaf chlorophyll has been related to an improved P_n in fescue [42] and various urban trees [43]. From these data, it seems that the impact of PGRs on photosynthesis is dependent on the specific plant species and environmental conditions.

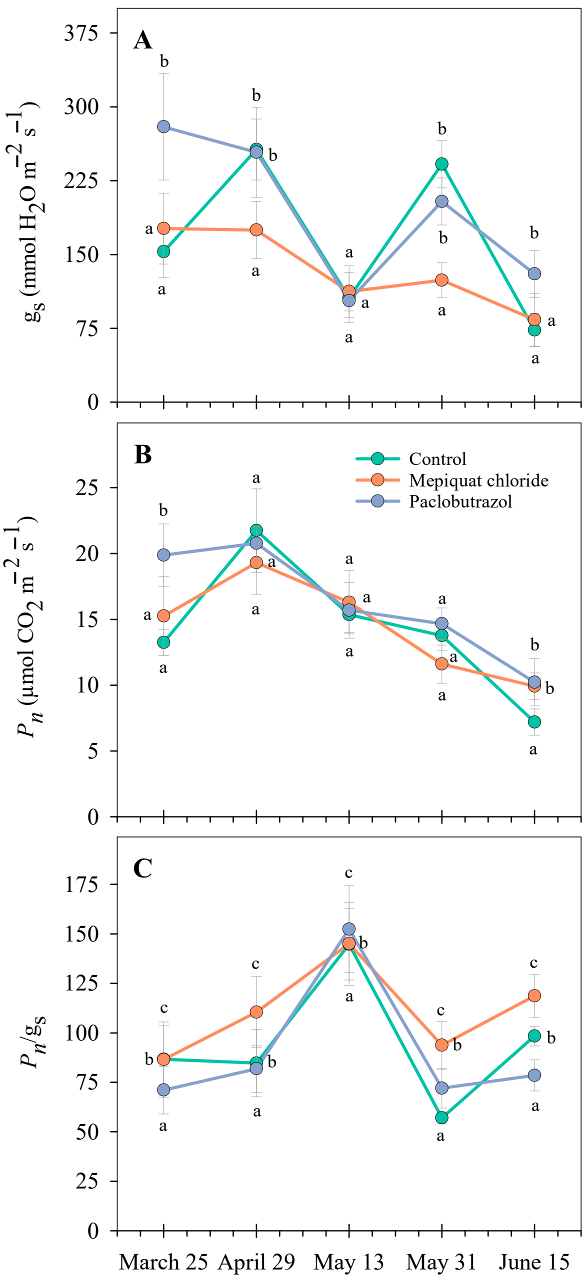

Figure 2. Stomatal conductance (g_s) (**A**), photosynthetic rate (P_n), (**B**) and intrinsic water use efficiency (P_n/g_s) (**C**) at midday from March to June. Each data point represents an average of six measurements, and vertical bars indicate standard error. Statistically significant differences between means ($p < 0.05$) are indicated by different letters in the same row, according to the LSD test.

3.4. Chlorophyll Fluorescence

At the end of the experiment, the stability of the PSII of the sage plants was evaluated by measuring their chlorophyll fluorescence parameters. Both the maximum quantum yield of Photosystem II (F_v/F_m) and the effective quantum yield (éPSII) serve as direct indicators of the photochemical efficiency of leaves. The results showed that PBZ and MC had no impact on F_v/F_m or éPSII, compared to the control. Thus, all values of F_v/F_m and éPSII were around 0.83 and 0.4, respectively (Figure 3), indicating that all plants had suitable photochemical functioning and were able to use the absorbed light energy efficiently [44].

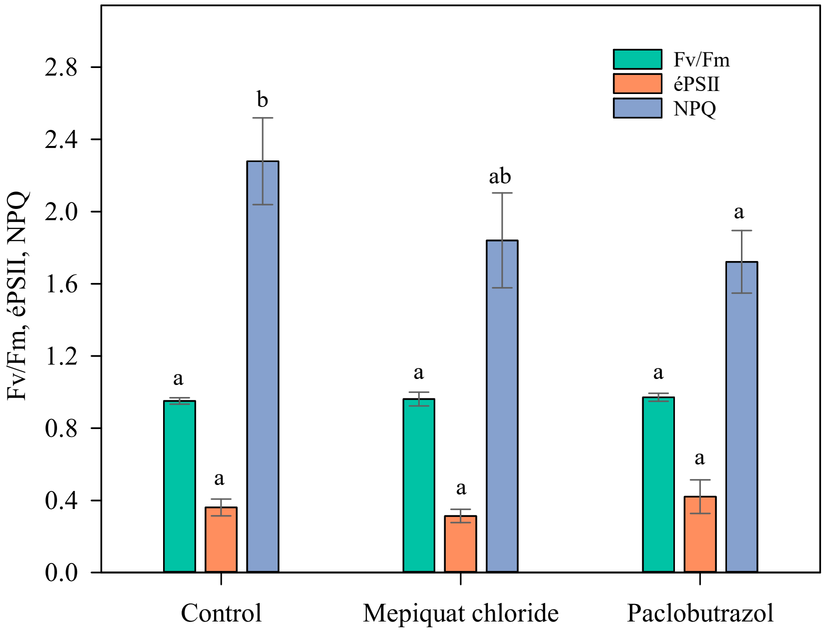

Figure 3. Chlorophyll fluorescence parameters in Icterina sage leaves at the conclusion of the experiment: maximum PSII quantum yield (F_v/F_m), effective quantum yield (éPSII), and non-photochemical quenching (NPQ). The vertical bars denote the standard error of the means (n = 6). The use of different letters means statistically significant differences between treatments determined at a significance level of $p < 0.05$ by the least significant difference (LSD) test.

PBZ-treated plants reduced non-photochemical quenching (NPQ) compared to the control, while MC did not produce significant effects. NPQ reflects the protective system of the plant against excess excitation energy, which is released as heat [45]. The values obtained here indicate that the plants were properly dissipating the excess quantum yield due to environmental stress, thus minimizing the generation of reactive oxygen species that would damage PSII [44]. The reduction in NPQ by PBZ suggests that the PBZ-treated sage plants were the least stressed as they had less excess energy to release. Different studies have reported that PBZ-treated plants show an increased resistance to abiotic and biotic stresses [1]; it has been related to the influence of PBZ on hormonal balance and gene expression [46]. Triazoles such as PBZ have been documented to impact the isoprenoid pathway and modify specific hormone levels. This effect is achieved by promoting the buildup of ABA in the leaves, elevating cytokinin concentrations, decreasing ethylene release, and inhibiting gibberellin production [39].

3.5. Plant Mineral Content

Table 2 displays the effect of MC and PBZ on the concentration of mineral ions in leaves, shoots, and roots. Regarding macronutrients (N, P, and K^+), the application of MC led to a significant increase in NO_3^- accumulation in all plant organs, with the highest accumulation in shoots and roots (89% and 60% relative to the control, respectively). In contrast, PBZ had no significant effect on NO_3^- content in sage. The ability of MC to retain nitrates in plant tissues is not a concern for ornamental plants since they are not meant for consumption. This characteristic might help mitigate the potential negative impact of nitrates on groundwater contamination by minimizing their release into the surrounding environment. On the other hand, MC caused a considerable accumulation of P in leaves (121% compared to the control), but surprisingly, no significant effect was observed in shoot P content. PBZ did not cause any significant changes in the P content in the plants. MC-treated plants exhibited a significant increase in K^+ in leaves (about 58% compared to the control), while PBZ fairly reduced the K^+ content in all three plant organs analyzed (Table 2). This increase is important because potassium enhances crop quality and disease resistance by participating in many vital processes such as osmoregulation, stomatal regulation, and photosynthesis [47].

Table 2. Effects of MC and PBZ on the mineral ion content in leaves, shoots, and roots of Icterina sage plants.

Element (mg g^{-1})	Plant Organ	Control	Mepiquat	Paclobutrazol
NO_3^-	Leaves	7.42 a	9.94 b	6.62 a
	Shoots	6.08 a	11.48 b	6.45 a
	Roots	6.9 a	11.05 b	6.42 a
P	Leaves	1.19 a	2.64 b	1.2 a
	Shoots	1.42 a	1.39 a	1.31 a
	Roots	1.46 a	1.73 b	1.28 a
K^+	Leaves	1.48 b	2.34 c	1.21 a
	Shoots	1.64 b	1.68 b	1.39 a
	Roots	1.72 b	1.86 b	1.29 a
Ca^{2+}	Leaves	6.17 a	10.45 c	8.58 b
	Shoots	8.4 a	9.59 ab	10.51 b
	Roots	9.08 a	9.59 a	9.47 a
Mg^{2+}	Leaves	4.82 a	5.88 b	5.93 b
	Shoots	6.02 ab	5.2 a	6.27 b
	Roots	5.42 a	5.05 a	5.3 a
Cl^-	Leaves	7.42 a	23.57 b	33.1 c
	Shoots	6.08 a	28.67 b	37.2 c
	Roots	6.9 a	24.51 b	29.05 c
Na^+	Leaves	7.35 a	6.75 a	10.1 b
	Shoots	7.84 a	6.98 a	11.06 b
	Roots	6.74 a	6.63 a	9.26 b

The use of different letters means statistically significant differences between treatments deter-mined at a significance level of $p < 0.05$ via the least significant difference (LSD) test.

According to the results, the application of MC can enhance sage nutrition effectively and might lower fertilizer costs. The ability of MC to change macronutrient foliar content was also observed in a study by Yang et al. [48]—the authors who found that MC increased significantly the N and P contents in cotton leaves. Other studies indicate that MC affected nutrient content in cotton plants by altering the way nutrients are distributed and absorbed [26]. For PBZ, the scientific literature indicates that its effect on macronutrient content is difficult to predict. Symons and Wolstenholme [49] found a decrease in N and K^+ in PBZ-treated avocado plants, but found no change in P, while Rieger and Scalabrelli [50] reported a decrease in all three macronutrients in PBZ-treated peach trees.

The application of MC increased the foliar Ca^{2+} by 69% but did not affect the Ca^{2+} levels in the shoots and roots (Table 2). Meanwhile, using PBZ increased the Ca^{2+} levels in the aerial part of the plant, but not in the roots. Other studies have reported an increase [50], a decrease [49], and no effects [51] on the Ca^{2+} content in the leaves of several trees. Both MC and PBZ increased the foliar Mg^{2+} content by 22% and 23%, respectively, but did not significantly change its content in the shoot and root. Since Mg^{2+} is important for chlorophyll synthesis and maintaining the function of chloroplasts [52], the increase in this nutrient in the leaves of PGRs-treated sage plants could be related to the presence of visually greener leaves.

Regarding more saline ions, both MC and PBZ produced a strong accumulation of Cl^- in leaves, shoots, and roots (Table 2). Plants treated with MC increased the Cl^- content in the shoot 4.7 times that of the control, and 3.2 and 3.6 times that of the leaves and roots. MC had no significant effect on Na^+ content in the three organs. However, in cotton, it has been suggested that MC favored Na^+ mobility by promoting its transport [12]. PBZ increased Cl^- contents between 4.2 and 6.1 times higher than the control, depending on the organ (Table 2). However, other studies indicate the ability of PBZ to decrease Cl^- and Na^+ content in tissues [53,54], but most of them have been performed under some stress, which highlights the PBZ protective effect against stress. The accumulation of Cl^- and/or Na^+ in the tissues decreases the osmotic potential of the plant, which could explain the increase in RWC in plants treated with PBZ, since a more negative osmotic potential reduces the water potential, helping to maintain hydration under drought or salinity, which allows photosynthesis to take place.

PBZ and MC protect sage against stress and enhance plant structure, growth control, and plant quality. These chemicals are tools that farmers can use to conserve resources when cultivating potted sage. However, it is important to recognize the associated limitations like environmental pollution, leaf discoloration, or phytotoxicity when used at high doses. Their effectiveness hinges upon the precise control of dosages, environmental conditions, and application techniques. Also, the environmental impact of PGRs emphasizes the need to balance their benefits with environmental concerns. This can be achieved by seeking synergistic effects through the simultaneous use of multiple PGRs, along with non-chemical growth control techniques such as minimal leaching, deficit irrigation, or light quality regulation.

4. Conclusions

Paclobutrazol and mepiquat chloride alter the growth, development, and water relations of *Salvia officinalis* Icterina. In comparison, paclobutrazol is more effective in sage than mepiquat chloride, especially in reducing leaf growth and water use, although both compounds accumulate solutes in leaves, regulating the osmotic balance. Mepiquat chloride improves nutrient absorption, which reduces the need for fertilizers and minimizes the potential impact of runoff on groundwater. Both phytoregulators contribute to sustaining photosynthesis under ambient stress. Paclobutrazol diminishes the non-photochemical quenching of the PSII, indicative of sage's tolerance to heat and dry ambient conditions. Both compounds enhance sage production, especially when precise growth management or resilience to harsh conditions is needed. In order to ensure a responsible application of these phytoregulators, we need to use them carefully and find ways to reduce their potential harm to the environment.

Author Contributions: Conceptualization, S.B.; methodology, S.B. and B.L.P.; software, S.B. and D.B.; validation, D.B., B.L.P. and M.J.S.-B.; formal analysis, S.B. and D.B.; investigation, S.B., B.L.P. and D.B.; resources, M.J.S.-B. and M.F.O.; writing—original draft preparation, S.B. and D.B.; writing—review and editing, S.B., D.B. and M.J.S.-B.; visualization, S.B. and D.B.; supervision, S.B.; project administration, M.J.S.-B. and M.F.O.; funding acquisition, M.J.S.-B. and M.F.O. All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded by the AGROALNEXT program supported by MCI-NextGenerationEU (PRTR-C17.I1) and Fundación Séneca-Región.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Desta, B.; Amare, G. Paclobutrazol as a Plant Growth Regulator. *Chem. Biol. Technol. Agric.* **2021**, *8*, 1. [CrossRef]
2. Bañón, S.; Fernández, J.A.; Ochoa, J.; Sánchez-Blanco, M.J. Paclobutrazol as an Aid to Reduce Some Effects of Salt Stress in Oleander Seedlings. *Eur. J. Hortic. Sci.* **2005**, *70*, 43–49.
3. Navarro, A.; Sanchez-Blanco, M.J.; Morte, A.; Bañón, S. The Influence of Mycorrhizal Inoculation and Paclobutrazol on Water and Nutritional Status of *Arbutus unedo* L. *Environ. Exp. Bot.* **2009**, *66*, 362–371. [CrossRef]

4. Rademacher, W. Plant Growth Regulators: Backgrounds and Uses in Plant Production. *J. Plant Growth Regul.* **2015**, *34*, 845–872. [CrossRef]
5. Sajjad, Y.; Jaskani, M.J.; Asif, M.; Qasim, M. Application of Plant Growth Regulators in Ornamental Plants: A Review. *Pak. J. Agric. Sci.* **2017**, *54*, 327–333.
6. Guimarães, R.F.B.; Maia Júnior, S.d.O.; Lima, R.F.d.; Souza, A.R.d.; Andrade, J.R.d.; Nascimento, R.d. Growth and Physiology of Ornamental Sunflower under Salinity in Function of Paclobutrazol Application Methods. *Rev. Bras. Eng. Agrícola E Ambient.* **2021**, *25*, 853–861. [CrossRef]
7. Ju, S.; Xu, D.; Zhan, C.; Ji, L.; Yin, T.; Li, Z.; Lu, Z. Influence of Paclobutrazol on the Growth and Photosynthesis of Seedlings. *J. Hortic. Res.* **2019**, *27*, 21–30. [CrossRef]
8. Hütsch, B.W.; Schubert, S. Water-Use Efficiency of Maize May Be Increased by the Plant Growth Regulator Paclobutrazol. *J. Agron. Crop Sci.* **2021**, *207*, 521–534. [CrossRef]
9. Soumya, P.R.; Kumar, P.; Pal, M. Paclobutrazol: A Novel Plant Growth Regulator and Multi-Stress Ameliorant. *Indian J. Plant Physiol.* **2017**, *22*, 267–278. [CrossRef]
10. Tung, S.A.; Huang, Y.; Ali, S.; Hafeez, A.; Shah, A.N.; Song, X.; Ma, X.; Luo, D.; Yang, G. Mepiquat Chloride Application Does Not Favor Leaf Photosynthesis and Carbohydrate Metabolism as Well as Lint Yield in Late-Planted Cotton at High Plant Density. *Field Crop. Res.* **2018**, *221*, 108–118. [CrossRef]
11. Tashmatova, M.; Azizov, B.; Aberkulov, M.; Baboev, S.; Ikromov, O. Use of Retardants Against Lodging of Medium-Sized Soft Wheat Varieties. In Proceedings of the XV International Scientific Conference "INTERAGROMASH 2022", Rostov-on-Don, Russia, 25 May 2022; Beskopylny, A., Shamtsyan, M., Artiukh, V., Eds.; Springer International Publishing: Cham, Switzerland, 2023; pp. 2179–2186.
12. Wang, X.; Zhou, Q.; Wang, X.; Song, S.; Liu, J.; Dong, S. Mepiquat Chloride Inhibits Soybean Growth but Improves Drought Resistance. *Front. Plant Sci.* **2022**, *13*, 982415. [CrossRef] [PubMed]
13. Karabacak, E.; Uysal, İ.; Doğan, M. Cultivated Salvia Species in Turkey. *Biyolojik Çeşitlilik Koruma* **2009**, *2*, 71–77.
14. Singh, V.; Sood, R.; Ramesh, K.; Singh, B. Effects of Growth Regulator Application on Growth, Flower, Oil Yield, and Quality of Clary Sage (*Salvia sclarea* L.). *J. Herbs Spices Med. Plants* **2008**, *14*, 29–36. [CrossRef]
15. Snyder, R.; Shaw, R.H.; Dawld, K.T. Vapour Pressure Deficit and Other Psychrometric Properties of Air from Temperature and Relative Humidity. *Agric. Res.* **1986**, *2*, 183–192.
16. Valdés, R.; Miralles, J.; Ochoa, J.; Sánchez-Blanco, M.J.; Bañón, S. Saline Reclaimed Wastewater Can Be Used to Produce Potted Weeping Fig (*Ficus benjamina* L.) with Minimal Effects on Plant Quality. *Span. J. Agric. Res.* **2012**, *10*, 1167–1175. [CrossRef]
17. Inskeep, W.P.; Bloom, P.R. Extinction Coefficients of Chlorophyll a and B in n,n-Dimethylformamide and 80% Acetone. *Plant Physiol.* **1985**, *77*, 483–485. [CrossRef]
18. Zhang, S.Y.; Zhang, G.C.; Liu, X.; Xia, J.B. The Responses of Photosynthetic Rate and Stomatal Conductance of Fraxinus Rhynchophylla to Differences in CO_2 Concentration and Soil Moisture. *Photosynthetica* **2013**, *51*, 359–369. [CrossRef]
19. Miralles, J.; Martínez-Sánchez, J.J.; Franco, J.A.; Bañón, S. Rhamnus Alaternus Growth under Four Simulated Shade Environments: Morphological, Anatomical and Physiological Responses. *Sci. Hortic.* **2011**, *127*, 562–570. [CrossRef]
20. Matsoukis, A.; Gasparatos, D.; Chronopoulou-Sereli, A. Mepiquat Chloride and Shading Effects on Specific Leaf Area and K, P, Ca, Fe and Mn Content of *Lantana camara* L. *Emir. J. Food Agric.* **2015**, *27*, 121–125. [CrossRef]
21. Ahmade, E. Effect of Pinching and Paclobutrazol on Growth and Flowering of Garland Chrysanthemum (*Chrysanthemum coronarium* L.). *Syr. J. Agric. Res.* **2019**, *6*, 409–419.
22. Chaney, W.R. *Growth Retardants: A Promising Tool for Managing Urban Trees*; Purdue University: West Lafayette, IN, USA, 2005.
23. Maghsoudi, E.; Abbaspour, H.; Pirbalouti, A.G.; Saeidi-Sar, S. Effects of Paclobutrazol and 24-Epibrassinolide on Some Morphological and Biochemical Characteristics of Salvia Officinalis under Different Irrigation Regimes. *Iran. J. Plant Physiol.* **2020**, *11*, 3523–3532.
24. Symons, P.; Wolstenholme, B.N. Field Trial Using Paclobutrazol Foliar Sprays on Hass Avocado Trees. *S. Afr. Avocado Grow. Assoc. Yearb.* **1990**, *13*, 35–36.
25. Wu, Q.; Du, M.; Wu, J.; Wang, N.; Wang, B.; Li, F.; Tian, X.; Li, Z. Mepiquat Chloride Promotes Cotton Lateral Root Formation by Modulating Plant Hormone Homeostasis. *BMC Plant Biol.* **2019**, *19*, 573. [CrossRef]
26. Almeida, A.Q.d.; Rosolem, C.A. Cotton Root and Shoot Growth as Affected by Application of Mepiquat Chloride to Cotton Seeds. *Acta Sci. Agron.* **2012**, *34*, 61–65. [CrossRef]
27. Jaleel, C.A.; Gopi, R.; Manivannan, P.; Panneerselvam, R. Responses of Antioxidant Defense System of Catharanthus Roseus (L.) G. Don. to Paclobutrazol Treatment under Salinity. *Acta Physiol. Plant* **2007**, *29*, 205–209. [CrossRef]
28. Sheena, A.; Sheela, V.L. Effects of the Growth Retardant Triadimefon on the Ex Vitro Establishment of Gladiolus (*Gladiolus grandiflorus* L.) Cv. Vinks Glory. *Plant Tissue Cult. Biotechnol.* **2010**, *20*, 171–178. [CrossRef]
29. Tung, S.A.; Huang, Y.; Hafeez, A.; Ali, S.; Liu, A.; Chattha, M.S.; Ahmad, S.; Yang, G. Morpho-Physiological Effects and Molecular Mode of Action of Mepiquat Chloride Application in Cotton: A Review. *J. Soil. Sci. Plant Nutr.* **2020**, *20*, 2073–2086. [CrossRef]
30. Matsoukis, A.S.; Tsiros, I.; Kamoutsis, A. Leaf Area Response of *Lantana camara* L. subsp. *camara* to Plant Growth Regulators under Different Photosynthetic Flux Conditions. *HortScience* **2004**, *39*, 1042–1044. [CrossRef]
31. Berova, M.; Zlatev, Z. Physiological Response and Yield of Paclobutrazol Treated Tomato Plants (*Lycopersicon Esculentum Mill.*). *Plant Growth Regul.* **2000**, *30*, 117–123. [CrossRef]

32. Marshall, J.; Beardmore, T.; Whittle, C.A.; Wang, B.; Rutledge, R.G.; Blumwald, E. The Effects of Paclobutrazol, Abscisic Acid, and Gibberellin on Germination and Early Growth in Silver, Red, and Hybrid Maple. *Can. J. For. Res.* **2000**, *30*, 557–565. [CrossRef]
33. Navarro, A.; Sánchez-Blanco, M.J.; Bañón, S. Influence of Paclobutrazol on Water Consumption and Plant Performance of Arbutus Unedo Seedlings. *Sci. Hortic.* **2007**, *111*, 133–139. [CrossRef]
34. Mohamed, G.F.; Agamy, R.A.; Rady, M.M. Ameliorative Effects of Some Antioxidants on Water-Stressed Tomato (*Lycopersicon Esculentum Mill.*) Plants. *J. Appl. Sci. Res.* **2011**, *7*, 2470–2478.
35. Maghsoudi, E.; Abbaspour, H.; Ghasemi Pirbalouti, A.; Saeidi-Sar, S. Influence of the Foliar Applications of Paclobutrazol and 24-Epibrassinolide on the Quantitative and Qualitative Traits of Sage (*Salvia officinalis* L.) Volatile Oil Under Different Soil Moisture Conditions. *J. Plant Growth Regul.* **2023**. [CrossRef]
36. Kishorekumar, A. Differential Effects of Hexaconazole and Paclobutrazol on the Foliage Characteristics of Chinese Potato (*Solenostemon Rotundifolius Poir.*, JK Morton). *Acta Biol. Szeged.* **2006**, *50*, 127–129.
37. Zhu, L.-H.; van de Peppel, A.; Li, X.-Y.; Welander, M. Changes of Leaf Water Potential and Endogenous Cytokinins in Young Apple Trees Treated with or without Paclobutrazol under Drought Conditions. *Sci. Hortic.* **2004**, *99*, 133–141. [CrossRef]
38. Ahmad Nazarudin, M.R. Plant Growth Retardants Effect on Growth and Flowering of Potted *Hibiscus rosa-sinensis* L. *J. Trop. Plant Physiol.* **2012**, *4*, 29–40.
39. Fletcher, R.A.; Gilley, A.; Sankhla, N.; Davis, T.D. Triazoles as Plant Growth Regulators and Stress Protectants. In *Horticultural Reviews*; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 1999; pp. 55–138. ISBN 978-0-470-65077-6.
40. Reddy, A.R.; Reddy, K.R.; Hodges, H.F. Mepiquat Chloride (PIX)-Induced Changes in Photosynthesis and Growth of Cotton. *Plant Growth Regul.* **1996**, *20*, 179–183. [CrossRef]
41. Rosolem, C.A.; Oosterhuis, D.M.; Souza, F.S. de Cotton Response to Mepiquat Chloride and Temperature. *Sci. Agric.* **2013**, *70*, 82–87. [CrossRef]
42. Liu, B.; Long, S.; Liu, K.; Zhu, T.; Gong, J.; Gao, S.; Wang, R.; Zhang, L.; Liu, T.; Xu, Y. Paclobutrazol Ameliorates Low-Light-Induced Damage by Improving Photosynthesis, Antioxidant Defense System, and Regulating Hormone Levels in Tall Fescue. *Int. J. Mol. Sci.* **2022**, *23*, 9966. [CrossRef]
43. Cregg, B.; Ellison-Smith, D. Application of Paclobutrazol to Mitigate Environmental Stress of Urban Street Trees. *Forests* **2020**, *11*, 355. [CrossRef]
44. Landis, T.D.; Nisley, R.G. *The Container Tree Nursery Manual: Seedling Processing, Storage, and Outplanting*; US Department of Agriculture, Forest Service: Washington, DC, USA, 2010; Volume 674, ISBN 9781782662419.
45. Maxwell, K.; Johnson, G.N. Chlorophyll Fluorescence—A Practical Guide. *J. Exp. Bot.* **2000**, *51*, 659–668. [CrossRef] [PubMed]
46. Kishore, K.; Singh, H.S.; Kurian, R.M. Paclobutrazol Use in Perennial Fruit Crops and Its Residual Effects: A Review. *Indian J. Agric. Sci.* **2015**, *85*, 863–872. [CrossRef]
47. Pettigrew, W.T. Potassium Influences on Yield and Quality Production for Maize, Wheat, Soybean and Cotton. *Physiol. Plant.* **2008**, *133*, 670–681. [CrossRef] [PubMed]
48. Yang, F.; Du, M.; Tian, X.; Eneji, A.E.; Duan, L.; Li, Z. Plant Growth Regulation Enhanced Potassium Uptake and Use Efficiency in Cotton. *Field Crop. Res.* **2014**, *163*, 109–118. [CrossRef]
49. Symons, P.R.R.; Hofman, P.J.; Wolstenholme, B.N. Responses to Paclobutrazol of Potted "Hass" Avocado Trees. In Proceedings of the Acta Horticulturae (Netherlands), Nelspruit, South Africa, 6 November 1989; ISHS: Leuven, Belgium, 1990.
50. Rieger, M.; Scalabrelli, G. Paclobutrazol, Root Growth, Hydraulic Conductivity, and Nutrient Uptake of Nemaguard'Peach. *HortScience* **1990**, *25*, 95–98. [CrossRef]
51. Swietlik, D.; Miller, S.S. The Effect of Paclobutrazol on Mineral Nutrition of Apple Seedlings. *J. Plant Nutr.* **1985**, *8*, 369–382. [CrossRef]
52. Rout, G.R.; Sahoo, S. Role of Iron in Plant Growth and Metabolism. *Rev. Agric. Sci.* **2015**, *3*, 1–24. [CrossRef]
53. Ahmed, M.; Shahin, S. Effect of Magnetite and Paclobutrazol on Growth and Chemical Composition of Schefflera Arboricola Endl. Cv. Gold Capella Plant under Salt Stress Conditions. *Egypt. J. Chem.* **2023**. [CrossRef]
54. Kitayama, M.; Tisarum, R.; Samphumphuang, T.; Cha-um, K.; Takagaki, M.; Himanshu, S.K.; Cha-um, S. Promotion of Mineral Contents and Antioxidant Compounds in Water Spinach Using Foliar Paclobutrazol and Salt Elicitors. *J. Soil Sci. Plant Nutr.* **2023**, *23*, 275–289. [CrossRef]