The Dwarfing Effects of Different Plant Growth Retardants on Magnolia wufengensis L.Y. Ma et L. R. Wang

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Abstract: The effects of varieties, concentrations, and number of applications of plant growth retardants (PGRs) on the morphological, physiological, and endogenous hormones of Magnolia wufengensis L.Y. Ma et L. R. Wang were assessed to obtain the most suitable dwarfing protocol for M. wufengensis and to provide theoretical support and technical guidance for the cultivation and promotion of this species. One-year-old M. wufengensis 'Jiaohong No. 2' grafted seedlings served as the experimental materials. In the first part of the experiment, three PGRs (uniconazole, paclobutrazol, prohexadione calcium), three concentrations (500, 1000, 1500 ppm), and three applications (one, three, and five applications) were applied in dwarfing experiments to perform L9 (3^4) orthogonal tests. In the second part of the study, dwarfing experiments were supplemented with different high uniconazole concentrations (0, 1500, 2000, 2500 ppm). Spraying 1500 ppm uniconazole five times achieved the best M. wufengensis dwarfing effect, related indicators of M. wufengensis under this treatment were better than other treatment combinations. Here, M. wufengensis plant height, internode length, scion diameter, and node number were significantly reduced by 56.9%, 62.6%, 72.8%, and 74.4%, respectively, compared with the control group. This treatment increased superoxide dismutase (SOD) activity by 66.0%, peroxidase (POD) activity by 85.0%, soluble protein contents by 43.3%, and soluble sugar contents by 27.6%, and reduced malondialdehyde (MDA) contents by 32.1% in leaves of M. wufengensis compared with the control. The stress resistance of M. wufengensis was enhanced. The treatment also reduced gibberellin (GA_3) levels by 73.0%, auxin (IAA) by 58.0%, and zeatin (ZT) by 70.6%, and increased (abscisic acid) ABA by 98.1% in the leaves of M. wufengensis. The uniconazole supplementation experiment also showed that 1500 ppm was the optimal uniconazole concentration. The leaves exhibited abnormalities such as crinkling or adhesion when 2000 or 2500 ppm was applied. Given the importance of morphological indicators and dwarfing for the ornamental value of M. wufengensis, the optimal dwarfing treatment for M. wufengensis was spraying 1500 ppm uniconazole five times.

Keywords: Magnolia wufengensis; dwarf; plant growth retardant; endogenous hormones; morphology; physiology

1. Introduction

Magnolia wufengensis L.Y. Ma et L. R. Wang and its variant Magnolia wufengensis var. multitepala are a new species of genus and subgenus Magnolia that were discovered by Professor Ma Luyi of Beijing Forestry University in Wufeng County, Hubei Province, China in 2004 [1,2]. M. wufengensis is a tall tree with a height of 20 m, and the crown is beautiful [1,2]. Its most distinctive feature is that it is the only species of Magnolia that is completely red inside and outside the perianth [3]. Its flowers are rich in morphological variations and exhibit different types, such as rose and lotus. There are also various tepal colors, ranging from purple-red to red to pale red and even close to white, and the number of petals in the perianth varies from nine to 46 [3]. Therefore, M. wufengensis exhibits a very high ornamental value and is an excellent ornamental tree species [4]. At present,
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eight new varieties have been selected and authorized, among which the new variety *Magnolia wufengensis ‘JiaoHong 1’* has been widely introduced as a city garden greening tree species to cities such as Yunnan, Guangxi, Guizhou, Henan, Jiangsu, Shandong, Beijing, Hebei, and other provinces in China [5]. Similar to a large number of Magnoliaceae plants, *M. wufengensis* has strong foliage and properties that improve its viewing and can also be used for garden greening [6]. However, *M. wufengensis* is too tall for indoor cultivation. Therefore, from the perspective of garden viewing, the dwarfing of *M. wufengensis* into a small garden tree or indoor potted plant can save space and allow adaptation to limited indoor heights. After dwarfing, *M. wufengensis* can integrate harmoniously with other plants and improve their overall ornamental effect. Furthermore, it is also convenient to be able to move potted plants, and dwarfing can extend its industrial chain to further increase its ornamental and economic value.

Dwarfing is an important process and is a hot topic in current plant work. Miniaturized and compact potted flowers and bonsai are becoming increasingly popular. Therefore, dwarfing is an important aspect of the ideal plant type of higher plants [7]. Common dwarfing methods can be roughly divided into chemical and physical methods. The physical methods mainly include dense dwarfing [8], grafting dwarfing anvil [9], and pruning dwarfing [10]. The chemical methods mainly include the application of plant growth retardants [11], virus dwarfing [12], and radiation-induced dwarfing [13]. Among these methods, the application of plant growth retardants (PGRs) effectively dwarfing ornamental plants and having the advantages of being inexpensive, easy and rapid, with high efficiency and minimal side effects, has become one of the important measures for modern agriculture [14].

There are many studies on the application of PGRs (Plant growth retardants) in tree species at home and abroad, and these methods have been successfully used to dwarf apple, pear, peach, arbutus, and other trees, achieving good modeling effects [15,16]. At present, PGRs are mainly quaternary ammonium salts (chlormequat chloride, mepperidone), triazoles (paclobutrazol, uniconazole), and cyclohexanecarboxylic acids (prohexadione calcium, trinexapac-ethyl). PGRs operate by inhibiting the synthesis of plant gibberellin (GA3), cell division, and elongation and growth of the lower part of the top of the stem, thereby inhibiting the vegetative growth of plants to a certain extent and achieving dwarfing [17]. PGRs promote plant photosynthesis and metabolism, significantly increase crop yield, and even promote flower bud differentiation and increase flower diameter [17]. Among PGRs, paclobutrazol has a remarkable dwarfing effect and minimal side effects on fruit trees, vegetables, and ornamental plants, which has attracted international attention [18,19]. In the nineteenth century, Aron applied 1 g L⁻¹ paclobutrazol to ‘Minneola’ tangelo (*Citrus reticulata* Blanco × *Citrus paradisi* Macf.) before the rapid growth of new shoots in summer, and the length of the shoots was reduced by approximately 50% on average [20]. The use of 100 ppm paclobutrazol in the mid-leaf development period of *Sapindus mukorossi* (Gaertn.) can achieve the best dwarfing effect, inducing vigorous growth in *S. mukorossi*, significantly reducing plant height, thickening the stalk, and increasing the chlorophyll content [21]. Wang Fang studied the influence of different concentrations of paclobutrazol (PP333) on some physiological characteristics in leaves of *Rhododendron hybrids* ‘Cosmopolitan’ and found that paclobutrazol can significantly increase the activity of superoxide dismutase (SOD) and peroxidase (POD) enzymes in leaves and petals and reduce the content of malondialdehyde of *R. hybrids* [22]. Furthermore, paclobutrazol alters the endogenous hormone content in young leaves, inhibiting GA content and increasing abscisic acid (ABA) content [23]. Although paclobutrazol can be absorbed by various parts of the plant, its mobility in the plant is not good [20]. Therefore, the specific application method needs to be considered when using paclobutrazol, and the commonly used methods include foliar spraying and soil irrigation [24,25].

Uniconazole is a highly effective PGR that can change plant morphology and cause a series of physiological responses [26]. Repeated foliar application of uniconazole on *Citrus reticulata* fruit can effectively reduce shoot growth and the number of nodes, re-
ducing internode length [27]. Under stress conditions, uniconazole increases the activity of SOD, POD, and catalase (CAT) in rice seedlings, reduces the content of malondialdehyde (MDA), reduces electrolyte permeability, and increases the free proline content of metabolites in seedlings to improve stress resistance [28]. Spraying uniconazole under salt stress can increase the accumulation of ABA, cytokinin (CTK), crude protein, total soluble protein, proline, auxin (IAA), and GA3 in barley plants [29]. Compared with paclobutrazol, uniconazole is more easily degraded, and its soil residue is only one tenth of the former [30].

Prohexadione calcium works through foliar treatment and can inhibit the synthesis of gibberellin in plants, especially 3β-hydroxylation of GA1 to GA20, thereby inhibiting the stem elongation of many plants [31]. Kang treated Chinese cabbage with prohexadione calcium and found that the contents of GA3 and GA4 both decreased [32]. The application of 100 ppm prohexadione calcium can effectively reduce the growth of pear (Pyrus communis L.) shoots and enlarge the fruit [33]. Under conditions of low temperature stress, spraying prohexadione calcium results in a slow increase in the membrane lipid peroxidation product MDA; increases proline content; weakens the inhibition of SOD, POD, and CAT activity under cold stress, and enhances the enzyme activity [34]. Compared with paclobutrazol and uniconazole, the residual amount of prohexadione calcium is reduced, which is more friendly to the human body and the environment, and has no significant impact on subsequent crops [31]. Therefore, the effects of spraying PGR at different concentrations a different number of times on plant growth vary greatly [21–31].

The purpose of this study is to dwarf M. wufengensis. Based on previous experience with other tree species, we mainly chose to explore the effects of the PGRs paclobutrazol, uniconazole, and prohexadione calcium at different concentrations on the morphological and physiological properties and endogenous hormones of M. wufengensis. It is hoped that the most suitable PGR variety, concentration, and number of applications can be identified through experiments to obtain a cost-effective method for dwarfing M. wufengensis plants, thus providing theoretical support and technical guidance for the cultivation and promotion of M. wufengensis.

2. Materials and Methods

2.1. Study Area

The experiment started on July 1, 2016 and was performed in Wufeng County, Yichang City, Hubei Province, China (30°12’ N, 110°40’ E). This area is located in the southwest of Hubei Province and borders Hunan Province in the north. The region has a subtropical monsoon climate with sufficient light, four distinct seasons, high temperatures and rain in summer, and low temperatures and snow in winter.

2.2. Study Design

2.2.1. Dwarfing Experiment of the PGRs

We selected one-year-old grafted seedlings of M. wufengensis ‘JiaoHong 2’. These seedlings were provided by Wufeng Bo Ling Magnolia wufengensis Technology Development Co., Ltd., Hubei, China; exhibited good growth and uniform scion diameters and plant heights; and served as the experimental material.

Uniconazole, paclobutrazol, and prohexadione calcium were selected as the experimental PGRs. Uniconazole (5% WP) and paclobutrazol (15% WP) were provided by Sichuan Guoguang Agrochemical Co., Ltd., Sichuan China. Prohexadione calcium (5% WP) was provided by Anyang Quanfeng Biological Technology Co., Ltd., Henan China.

The 3 PGRs were used at 3 concentrations (500, 1000, and 1500 mg L⁻¹) and applied 1, 3, or 5 times. An orthogonal (L9 (3⁴)) experimental design was adopted in the experiment to yield a total of 9 treatments as shown in Table 1. Using the treatment without PGRs as a control group (CK), there were 10 treatments in total, and each treatment contained 15 seedlings repeated 3 times. The experiment was conducted from June 2016 to October 2016.
Table 1. L9 (3^4) orthogonal experimental design.

| Treatment Number | Variety     | Concentration (mg L\(^{-1}\)) | Number of Application (Times) | Empty Column |
|------------------|-------------|--------------------------------|-------------------------------|--------------|
| 1                | Uniconazole | 500                            | 1                             | 1            |
| 2                | Uniconazole | 1000                           | 3                             | 2            |
| 3                | Uniconazole | 1500                           | 5                             | 3            |
| 4                | Paclobutrazol| 500                            | 3                             | 3            |
| 5                | Paclobutrazol| 1000                           | 5                             | 1            |
| 6                | Paclobutrazol| 1500                           | 1                             | 2            |
| 7                | Prohexadione Calcium | 500                            | 5                             | 2            |
| 8                | Prohexadione Calcium | 1000                           | 1                             | 3            |
| 9                | Prohexadione Calcium | 1500                           | 3                             | 1            |

There are two rapid growth periods in the one-year growth season of *M. wufengensis* grafted seedlings: June and August. The PGRs were generally applied before the rapid growth of plants, i.e., in the early stage of rapid growth of *M. wufengensis* grafted seedlings (early June 2016). The application method was foliar spray. A pressure-type sprayer was used to spray water on the front and back of the foliage. Plants were not watered within 1 week after the application of the reagent to prevent the solution from being diluted. The interval between applications was 10 days until the number of applications used in the experiment was reached. If the plant encountered rain within two days of applying the PGR, the experiment was extended and sprayed at 10-day intervals.

2.2.2. Supplemental Dwarfing Experiments at Different Uniconazole Concentrations

According to the results of the PGR dwarfing experiment, the best dwarfing treatment was spraying 1500 ppm uniconazole 5 times, and the number of applications was the highest value set. However, spraying 5 times crossed from the first to the second growth peaks of *M. wufengensis*, so no additional experiments were applied to test the number of applications. The optimal PGR concentration obtained in the experiment was also the highest value set in the experiment. To determine the optimal concentration of uniconazole, this supplemental dwarfing experiment was added.

In this experiment, the *M. wufengensis ‘JiaoHong 2’* 1-year-old grafted seedlings with uniform scion diameters and plant heights that exhibited superior growth were selected as the experimental materials. The experiment was performed in a completely random block design, and a total of 4 treatments were employed, i.e., spraying uniconazole at 0, 1500, 2000, and 2500 ppm. Each treatment comprised 9 seedlings in plots and was repeated thrice. The experiment was conducted from June 2017 to October 2017.

2.3. Method

2.3.1. Morphological Investigation

In each plot, seedlings were randomly selected and morphologically investigated [7]. The plant height and scion base diameter were measured before the start of the experiment, and the number of nodes and internodal length were recorded. The scion diameter was measured 5 cm above the graft joint.

2.3.2. Determination of Physiological and Biochemical Indicators

Sampling was performed before the start of the experiment (early June) and two months after the experiment. The sampling time was 8 o’clock in the morning. For each treatment, 10 seedlings were randomly selected to pick 1–3 functional leaves (the 2nd–4th leaf from the top) in each plot, wrapped with tin foil, marked, fixed in liquid nitrogen and stored in a refrigerator at \(-80\) °C.
The measured indexes included SOD, POD, soluble protein, MDA, and soluble sugar. SOD activity was determined using the NBT reduction method [35]. POD activity was determined using the guaiacol chromogenic method [36]. MDA content was determined using the thiobarbituric acid method [37]. The content of soluble sugar was determined using anthrone colorimetry [35], and soluble protein was determined using the Coomassie blue method [38].

2.3.3. Determination of Endogenous Hormones

The sampling time, sampling method, and storage method were consistent with those used in the determination of physiological and biochemical indicators reported in Section 2.3.2. The samples were analyzed by high-performance liquid chromatography (HPLC) [39]. The measurement indicators included IAA, GA₃, ABA, and ZT content [39].

2.4. Data Processing

In this study, EXCEL (2007) and SPSS 19.0 statistical software were used for data statistics and analysis. A factorial analysis of variance (ANOVA) and the Duncan test \((p < 0.05)\) were performed to analyze the variance and for multiple comparisons.

3. Results

The conclusion is divided into two parts. Sections 3.1–3.3 report the dwarfing experiment of the PGRs, and Sections 3.4–3.6 describe the supplemental dwarfing experiment at different uniconazole concentrations.

3.1. Dwarfing Effects of PGRs on Morphology

The PGR variety, concentration, and number of applications could significantly affect plant scion diameter, plant height, number of nodes, and internodal length. The experimental results are shown in Table 2 and Figure 1.

In the range analysis, the larger the range value, the greater is the effect of this factor on the index. As shown in Table 2, the degree of influence of the three factors on the plant height of *M. wufengensis* exhibits the following order: concentration (43.1) > number of application (33.6) > variety (28.3). All factors had extremely significant effects \((p < 0.01)\). The concentration and number of applications of PGRs had a significant impact on the internodal length \((p < 0.01)\). Specifically, the concentration (2.5) had a greater impact, whereas the variety had no significant impact on internodal length \((p > 0.05)\). The concentration and variety of PGRs had a significant effect on the scion diameter of *M. wufengensis* \((p < 0.01)\), whereas the concentration (2.0), variety (1.9), and number of applications had no significant effect on the scion diameter \((p > 0.05)\). The variety of PGRs had a significant effect on the node number \((p < 0.01)\), and the concentration also had a significant effect \((p < 0.05)\). However, the number of applications had no significant effect on the node number \((p > 0.05)\). In summary, the concentration of PGRs has the strongest effect on the plant height, internodal length and scion diameter of *M. wufengensis*; it plays a leading role in the morphological indicators of *M. wufengensis*.

According to Figure 2, the plant height (Figure 2a), internodal length (Figure 2b), scion diameter (Figure 2c) and node number (Figure 2d) of *M. wufengensis* in the 10 treatments were significantly different \((p < 0.05)\). The minimum plant height was 115.8 cm for treatment No. 3, which was only 56.9% of the CK (203.4 cm) (Figure 2a). The minimum internodal length was noted for treatment No. 3 (6.2 cm), which was 62.6% of the CK (9.8 cm) (Figure 2b). The smallest scion diameter was noted for treatment No. 3 (13.5 mm), which was 72.8% of the largest scion diameter in CK (18.6 mm) (Figure 2c). Figure 2d shows that among the 10 treatments the node number of *M. wufengensis* was significantly lower than that of CK \((p < 0.05)\). The minimum node number was noted for treatment Nos. 1, 2, and 3, and the difference between them was not significant \((p > 0.05)\). The node number for treatment No. 3 (18.9) was 74.4% of the maximum node number of CK (25.4). In summary, No. 3 treatment (spraying 1500 ppm uniconazole five times) exhibited the best effect on
the dwarfing morphology *M. wufengensis*. Compared with CK, plant height, internodal length, scion diameter and node number were significantly reduced (56.9%, 62.6%, 72.8%, and 74.4% of CK, respectively).

![Figure 1](image_url)

**Figure 1.** The effects of different PGR treatments on the height (a), internodal length (b), scion diameter (c), and node number (d) of *Magnolia wufengensis* L.Y. Ma et L. R. Wang. Treatment No. 10 is the control group (CK). Different small letters indicate significant differences among treatments as assessed by the Duncan’s test (*p* < 0.05). Bras are means ± SDs (*n* = 3). The same is shown below.

| Range        | Height/cm | Internodal Length/cm | Scion Diameter/cm | Node Number |
|--------------|-----------|----------------------|-------------------|-------------|
| Variety      | 28.3 **   | 0.4                  | 1.9 **            | 3.6 **      |
| Concentration| 43.1 **   | 2.5 **               | 2.0 **            | 1.2 *       |
| Times        | 33.6 **   | 2.1 **               | 1.0               | 0.9         |

Note: * indicates the different varieties, concentrations, and times of PGRs significantly affect plant height, internodal length, scion diameter, and node number of *Magnolia wufengensis*. *, *p* < 0.05; **, *p* < 0.01. The same parameters are reported in Tables 3 and 4.

### 3.2. Dwarfing Effects of PGRs on Physiology

The PGR variety, concentration, and number of applications affected the SOD and POD activities and soluble protein, MDA, and soluble sugar content of *M. wufengensis* as shown in Table 3 and Figure 2.

As shown in Table 3, the variety of PGRs had a significant impact on SOD activity in *M. wufengensis* (*p* < 0.05). The PGR concentration (84.2) had a greater impact on SOD activity than the number of applications (74.3), but it was not significant (*p* > 0.05). The number of applications of PGRs had a significant impact on POD activity (*p* < 0.05), whereas the variety and concentration had no significant impact (*p* > 0.05). The variety and
number of applications of PGRs had a significant impact on the soluble protein content of \textit{M. wufengensis} \((p < 0.01)\). In addition, the number of applications \((14.4)\) had a greater impact than the variety \((11.6)\), but the concentration of PGRs had no significant effect on the soluble protein content \((p > 0.05)\). The 3 factors had no significant influence on the MDA content of \textit{M. wufengensis} \((p > 0.05)\). The 3 factors of PGRs on the content of soluble sugar, which is arranged as follows: concentration \((0.7)\) > variety \((0.6)\) > number of applications \((0.5)\). The concentration reached an extremely significant level \((p < 0.01)\), and the variety and number of applications reached a significant level \((p < 0.05)\). In summary, the variety of PGRs has the strongest effect on the SOD activity and MDA content of \textit{M. wufengensis}. The concentration has the strongest effect on the soluble sugar content, and the number of applications has the strongest effect on the POD activity and soluble protein content.

![Figure 2](image-url)

\textbf{Figure 2.} The effects of PGRs on SOD activity (a), POD activity (b), soluble protein (c), MDA content (d), and soluble sugar (e) of \textit{M. wufengensis}. 
Table 3. Range analysis of the L9 (3^4) orthogonal experimental design assessing physiological factors.

| Range          | SOD     | POD     | Soluble Protein | MDA    | Soluble Sugar |
|----------------|---------|---------|-----------------|--------|---------------|
| Variety        | 137.4 * | 12.8    | 11.6 **         | 1.5    | 0.6 *         |
| Concentration  | 74.3    | 34.9    | 4.7             | 1.1    | 0.7 **        |
| Times          | 84.2    | 131.6 * | 14.4 **         | 1.4    | 0.5 *         |

Note: * indicates the different varieties, concentrations and times of PGRs that significantly affect SOD and POD activity and the content of soluble protein, MDA and soluble sugar. *, p < 0.05; **, p < 0.01.

As shown in Figure 2, the effects of different treatment combinations on the SOD and POD activities and soluble protein, MDA, and soluble sugar content of *M. wufengensis* were significantly different (*p* < 0.05). The SOD activities with treatment Nos. 3 (780.6 U·mg⁻¹) and 2 (757.5 U·mg⁻¹) were significantly increased compared with CK. The SOD activity of *M. wufengensis* with treatment No. 3 was the strongest and was 66.0% higher than that in CK (470.1 U·mg⁻¹) (Figure 2a). Figure 2b shows that the POD activity of *M. wufengensis* with treatments No. 4 (316.5 U·g⁻¹·min⁻¹), No. 6 (335.3 U·g⁻¹·min⁻¹), and No. 8 (285.9 U·g⁻¹·min⁻¹) was not significantly different from CK (306.4 U·g⁻¹·min⁻¹) (*p* > 0.05), and the other treatments yielded results that were significantly increased compared with CK (*p* < 0.05). The POD activity of *M. wufengensis* with treatment No. 3 was the strongest (566.9 U·g⁻¹·min⁻¹), which was 85.0% higher than CK. Figure 2c shows that the soluble protein content of *M. wufengensis* with treatments No. 1 (10.6 mg·g⁻¹) and No. 6 (17.8 mg·g⁻¹) was not significant compared with CK (15.5 mg·g⁻¹) (*p* > 0.05), and the remaining treatments yield significantly higher values than CK (*p* < 0.05). The soluble protein content with treatment No. 9 was the highest (39.5 mg·g⁻¹), which was 154.8% higher than CK. The soluble protein content treatment No. 3 (27.8 mg·g⁻¹) was significantly increased by 43.3% compared with CK (*p* < 0.05). Figure 2d shows that compared with CK (17.6 umol·g⁻¹), different treatment combinations could significantly reduce the MDA content of *M. wufengensis* (*p* < 0.05). Treatment No. 3 (11.9 umol·g⁻¹) exhibited the lowest MDA content, which was 32.1% lower than the CK. Figure 2e shows that treatment No. 1 (5.2 mmol·g⁻¹), No. 4 (5.2 mmol·g⁻¹) and No. 7 (5.5 mmol·g⁻¹) were not significantly different from CK (5.0 mmol·g⁻¹) (*p* > 0.05), and the other treatments were significantly higher than CK (*p* < 0.05). The soluble sugar content was the highest treatment No. 3 (6.4 mmol·g⁻¹), which was increased by 27.6%, compared with CK. In summary, compared with CK, spraying 1500 ppm uniconazole five times with treatment No. 3 increased superoxide dismutase (SOD) and peroxidase (POD) activities in grafted seedlings of *M. wufengensis* by 66.0% and 85.0%, respectively. The soluble protein content increased by 43.3%, soluble sugar content increased by 27.6%, and malondialdehyde (MDA) content decreased by 32.1%.

### 3.3. Dwarfing Effects of PGRs on Endogenous Hormones

The variety, concentration, and number of applications of PGRs had different effects on the four endogenous hormones GA₃, IAA, ABA, and ZTs as shown in Table 4 and Figure 3.

Table 4. Range analysis of the L9 (3^4) orthogonal experimental design for endogenous hormones.

| Range          | GA₃     | IAA    | ABA    | ZT     |
|----------------|---------|--------|--------|--------|
| Variety        | 13.6    | 3.1 *  | 0.9    | 0.6    |
| Concentration  | 70.1 ** | 7.2 ** | 3.0 ** | 5.0 ** |
| Times          | 63.0 ** | 6.3 ** | 3.6 ** | 2.0 ** |

Note: * indicates the different varieties, concentrations and times of PGR treatments that significantly affect the content of GA₃, IAA, ABA and ZT. *, *p* < 0.05; **, *p* < 0.01.
Based on the range analysis results shown in Table 4, the concentration and times of PGR treatments had extremely significant effects on GA3, IAA, ABA, and ZT levels \( (p < 0.01) \), and the effects of both variables were greater than that noted for the variety of PGRs, which only had a significant effect on IAA content \( (p < 0.05) \). Among them, the influence of PGR concentration on GA3, IAA and ZT content was greater than that noted for the variety of PGR treatments, and the influence of ZT content was less than that noted for the number of applications.

As noted in Figure 3a, different PGR treatments had different effects on the GA3 content of *M. wufengensis*. Among them, the GA3 content of *M. wufengensis* with treatment Nos. 2 (34.5 \( \mu g \cdot g^{-1} \)), 3 (78.1 \( \mu g \cdot g^{-1} \)), and 9 (47.0 \( \mu g \cdot g^{-1} \)) was significantly reduced compared with the other treatments \( (p < 0.05) \). The GA3 content of *M. wufengensis* with treatment No. 3 was the lowest, which was 73.0% lower than CK (128.0 \( \mu g \cdot g^{-1} \)). Figure 3b shows that different PGR treatment combinations had different effects on the IAA content of *M. wufengensis*. The IAA content with treatment Nos. 3 (5.7 \( \mu g \cdot g^{-1} \)), 5 (5.2 \( \mu g \cdot g^{-1} \)), 6 (4.9 \( \mu g \cdot g^{-1} \)), and 9 (7.8 \( \mu g \cdot g^{-1} \)) was significantly reduced by 58.0%, 61.9%, 63.5%, and 42.1%, respectively, compared with that of the CK (13.5 \( \mu g \cdot g^{-1} \)), and the difference between them was not significant \( (p > 0.05) \). Figure 3c shows that different PGR treatment combinations had different effects on the ABA content of *M. wufengensis*. With the exception of the ABA content of *M. wufengensis* with treatment Nos. 1 (6.4 \( \mu g \cdot g^{-1} \)) and 4 (7.2 \( \mu g \cdot g^{-1} \)), which was not significantly different from CK (7.1 \( \mu g \cdot g^{-1} \)), the ABA contents of the other treatments were significantly greater compared with CK. Treatment No. 3 had the highest ABA content (14.0 \( \mu g \cdot g^{-1} \)), which was 98.1% higher than CK. Figure 3d shows that different PGR treatment combinations had different effects on the ZT content of *M. wufengensis*. Compared with CK (11.9 \( \mu g \cdot g^{-1} \)), except for treatment No. 1 (12.1 \( \mu g \cdot g^{-1} \)), which was not significantly different, the others were significantly lower than the value noted for CK. Treatment No. 3 (3.5 \( \mu g \cdot g^{-1} \)) had the lowest ZT content, which was 70.6% lower than that noted for CK. In summary, compared with CK, No. 3 treatment (spraying 1500 ppm

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**Figure 3.** The effects of PGRs on GA3 (a), IAA (b), ABA (c) and ZT (d) in *M. wufengensis*.
uniconazole 5 times) reduced GA$_3$ levels in leaves of *M. wufengensis* by 73.0%, IAA by 58.0% and ZT content by 70.6%, and increased the ABA content by 98.1%.

### 3.4. Effects of Different Concentrations of Uniconazole on Morphology

To determine the optimal concentration of uniconazole, a supplementary experimental test was conducted to examine the effects of different concentrations of uniconazole on *M. wufengensis*. According to the experimental results, different concentrations of uniconazole had different effects on the plant height, scion diameter, node number, and internodal length of *M. wufengensis*. The detailed results are shown in Figure 4.

![Figure 4](image_url)

**Figure 4.** The effects of different concentrations of uniconazole on height (a), internodal length (b), scion diameter (c), and node number (d) in *M. wufengensis*. Different small letters indicate significant differences among treatments as assessed by the Duncan’s test (*p* < 0.05). Bars represent means ± SDs (*n* = 3). The same is shown below.

According to the experimental results shown in Figure 4, the height (Figure 4a), scion diameter (Figure 4b), node number (Figure 4c) and internodal length (Figure 4d) of the grafted seedlings of *M. wufengensis* gradually decreased with increasing uniconazole concentrations. When the sprayed uniconazole concentration was 2500 ppm, the average plant height was the shortest (20.7 cm), the scion diameter was the smallest (5.1 mm), the node number was the smallest (5.3), and the internodal length was the shortest (3.9 cm) at 70.5%, 81.8%, 80.3%, and 88.1% of the average CK of the control group, respectively. Based on the above indicators, the higher the concentration of uniconazole sprayed, the better is the dwarfing effect. However, most of these morphological indicators were not significantly different (*p* > 0.05). Therefore, it can be determined that further increases in the concentration of uniconazole would have no significant effect on the morphological indicators. The use of a high concentration of uniconazole for foliar spraying of *M. wufengensis* caused leaf deformities. When the concentration of uniconazole was 2000 ppm, the newly formed leaves shrank and were lighter and more uneven in color than normal leaves. When 2000 ppm uniconazole was sprayed, adhesions appeared in the front part of some...
newborn leaves, and the ornamental nature of *M. wufengensis* was weakened. In summary, the optimal dwarfing concentration of uniconazole is 1500 ppm.

3.5. Effects of Different Concentrations of Uniconazole on Physiology

Foliar spraying of different concentrations of uniconazole had different effects on the physiology of grafted seedlings of *M. wufengensis*. This part of the experiment focused on the effects of different concentrations of uniconazole on SOD, POD, soluble protein, malondialdehyde (MDA), and soluble sugar as shown in Figure 5.

![Figure 5](image-url)

*Figure 5.* The effects of different concentrations of uniconazole on SOD activity (a), POD activity (b), soluble protein content (c), MDA content (d) and soluble sugar content (e) in *M. wufengensis.*
According to the experimental results shown in Figure 5, a high concentration of uniconazole caused the SOD activity (Figure 5a) and soluble sugar content (Figure 5e) of the grafted seedlings of *M. wufengensis* to initially increase and subsequently decrease, whereas POD activity (Figure 5b), soluble protein (Figure 5c) and MDA content (Figure 5d) increased. These effects were significant (*p* < 0.05). When 2000 ppm was applied, the highest SOD activity (855.2 U·mg⁻¹) and soluble sugar content (5.7 mmol·g⁻¹) were noted (182.1% and 128.6% of the control group, respectively). The POD activity (723.7 U·mg⁻¹·min⁻¹), soluble protein (26.5 mg·g⁻¹), and MDA content (9.8 umol·g⁻¹) reached the greatest levels when plants were sprayed with 2500 ppm uniconazole (124.4%, 159.1%, and 125.7% of the control group, respectively). Although the results of the physiological indicators indicated that *M. wufengensis* was more tolerant to uniconazole, spraying 2000 ppm uniconazole caused the leaves of *M. wufengensis* to be deformed in the experiment assessing the concentration of uniconazole. Therefore, considering the morphological indicators and given that dwarfing was mainly performed for the ornamental value of *M. wufengensis*, the optimal dwarfing concentration of uniconazole for *M. wufengensis* was 1500 ppm in this study.

### 3.6. Effects of Different Concentrations of Uniconazole on Endogenous Hormones

Foliar spraying with different concentrations of uniconazole had different effects on endogenous hormones in grafted seedlings of *M. wufengensis*. These experiments explored the effects of different concentrations of uniconazole on GA₃, IAA, ABA, and ZT as shown in Figure 6.

![Figure 6](image-url)

**Figure 6.** The effects of different concentrations of uniconazole on GA₃ (a), IAA (b), ABA (c) and ZT (d) content in *M. wufengensis*.

According to the experimental results shown in Figure 6, the contents of GA₃ (Figure 6a), IAA (Figure 6b), and ZT (Figure 6d) in *M. wufengensis* gradually decreased as the concentration of uniconazole increased, whereas the content of ABA (Figure 6c) gradually increased as the concentration of uniconazole increased. The difference between
the different concentrations of uniconazole was significant. Using 2500 ppm uniconazole, the contents of GA₃ (49.9 µg g⁻¹), IAA (6.6 µg g⁻¹), and ZT (4.7 µg g⁻¹) were the lowest, whereas the contents of ABA (2.9 µg g⁻¹) were the highest (20.2%, 55.2%, 33.6%, and 221.8% of the average content of the control group, respectively). Further increases in the uniconazole concentration had similar effects on endogenous hormones as the original concentration. These findings illustrate that the lower the GA₃, IAA, and ZT content, the greater is the ABA content. However, when 2000 ppm uniconazole is applied, it caused the leaves of *M. wufengensis* to become deformed. Therefore, the optimal dwarfing concentration of uniconazole for *M. wufengensis* was 1500 ppm.

4. Discussion

4.1. Dwarfing Effects of PGRs on Morphology

The dwarfing of tree species is an important method that is used for the commercial production of ornamental plants [40]. Plant dwarfing technology is a comprehensive and complex system that involves multiple factors, and the use of plant growth retardants can promote the dwarfing of many plants [15,16]. Plant dwarfing is not only related to the genetic characteristics of the plant itself, but also to the variety, concentration and number of applications of PGRs [22,32,33]. *M. wufengensis* is a tall tree species that is typically difficult to dwarf [1,2]. This study shows that the variety and concentration of PGRs have a significant impact on plant height, internode length and scion diameter of *M. wufengensis*. After spraying 500 ppm uniconazole five times, the optimal plant dwarfing effect was obtained. Compared with CK, the plant height, internode length, scion diameter and node number were reduced by 56.9%, 62.6%, 72.8%, and 74.4%, respectively, and these effects were also better than those noted with the paclobutrazol and prohexadione calcium. Cohen found that uniconazole more effectively reduced the height of tree trunks than paclobutrazol during the process of spraying two PGRs on date palm seedlings, thereby dwarfing plants for intensive management [41]. Gao Shurui studied the effects of different concentrations of uniconazole on the growth of *Salvia miltiorrhiza* and found that *S. miltiorrhiza* plants were significantly dwarfed after foliar sprays of uniconazole, which mainly manifested in a decrease in plant height, plant width, and height-to-diameter ratio [42]. Roux and GH Barr used different concentrations of paclobutrazol, uniconazole, and prohexadione calcium to spray the grafted seedlings of *Citrus lemon*, and the results showed that spraying of uniconazole can shorten the internode length by 50% and new shoots by 34%, and the plants were obviously dwarfed [42]. The results of this paper are similar to the above studies. The plant growth retardant mainly reduced the plant height and shortened the internode length to achieve plant dwarfing.

4.2. Dwarfing Effects of PGRs on Physiology

Plant growth retardants effectively increase the content of osmotic adjustment substances, increase the activity of antioxidant enzymes, delay the peroxidation of membrane lipids, and delay protein decomposition, thereby improving plant resistance and disease resistance [43,44]. In this study, treatment No. 3 showed the best treatment combination for dwarfing grafted seedlings of *M. wufengensis* obtained in the PGR dwarfing experiment (spraying 1500 ppm uniconazole 5 times). Compared with the control, this treatment increased the activity of SOD by 66.0%, the activity of POD by 85.0%, the content of soluble protein by 43.3%, and the content of soluble sugar by 27.6%, and it decreased MDA content by 32.1%. In the supplementary experiment assessing the uniconazole concentration, it was also found that an excessively high concentration of uniconazole resulted in further increases in SOD and POD activity as well as the content of soluble protein and soluble sugar and reduced the MDA content. SOD is a common biological enzyme that primarily functions to scavenge oxygen free radicals. Therefore, the level of SOD activity reflects the resistance of a plant to a certain extent. Higher SOD activity indicates that the plant is more capable of coping with environmental stress, disease, and senescence [45–47]. POD is an oxidoreductase that is closely related to plant respiration and photosynthesis. According
to previous research results, the higher the POD activity, the stronger is a plant’s ability to cope with adverse environments [48]. Soluble protein and soluble sugar have important effects on plant physiology and are closely related to plant stress resistance [49]. When plants experience stress, they can adapt by increasing the soluble protein content [50]. Increasing the soluble sugar content can improve plant cold resistance [51]. Excessive MDA content indicates a high degree of damage to the plant membrane system [52]. These five physiological indicators can jointly explain the strong ability of *M. wufengensis* to cope with adverse environmental conditions. Zhou Xiulin et al. used uniconazole to treat *Chlorophytum capense* within a certain concentration range and at various application times. These researchers demonstrated that uniconazole enhances antioxidant enzyme activity (including CAT, SOD, POD), reduces MDA content, and increases soluble protein and chlorophyll contents, thereby enhancing the stress resistance of *C. capense* [53]. Many studies have also demonstrated that spraying an appropriate concentration of uniconazole can delay plant growth, increase chlorophyll levels, increase leaf soluble sugar and soluble protein contents, promote antioxidant enzyme activity, enhance the cell’s ability to remove active oxygen, reduce the relative permeability of the plasma membrane, and improve plant resistance to stress [54–56]. Therefore, in this study, the application of uniconazole to the grafted seedlings of *M. wufengensis* not only dwarfed the plant but also improved the stress resistance of *M. wufengensis*.

### 4.3. Effects of PGRs on Endogenous Hormones

PGRs are a class of artificially synthesized hormones that are antagonists of GA, which can delay plant growth. The mechanism of PGRs mainly involves hindering the activity of certain enzymes during the synthesis of GA, which reduces GA levels in plants and thus inhibits cell elongation in the elongation zone between the stems, shortens the internode length, and achieves the effect of dwarfing in plants [57]. Some of the precursors of GA are closely related to IAA, ABA, CAT, and ethylene (ETH), so changes in GA content will affect the overall endogenous hormone levels of the plant [58]. Studies have demonstrated that uniconazole can reduce the formation of GA synthesis precursor materials by reducing the activity of kaurene oxidase, thereby inhibiting the biosynthesis of GA, reducing the level of endogenous GA, and reducing the content of IAA while increasing the content of ABA [59]. Yang Weiru’s research shows that the plant growth retardant chlormequat effectively inhibits the synthesis of gibberellin GA$_3$, IAA, and ZT and simultaneously affects the ABA content, thereby dwarfing the plant height of *Sanguisorba officinalis* [60]. Li Ningyi and Liu Bing used uniconazole to treat Lilium Asiatic Hybrids and found that it could significantly reduce the content of IAA and GA$_3$ and increase the content of zeatin nucleoside (ZR) and ABA. In addition, the effect gradually increased with an increasing treatment concentration, thereby inhibiting the elongation of plant cells and resulting in lower plant height [61]. Therefore, in this study, spraying uniconazole on *M. wufengensis* reduced the content of GA$_3$, IAA, and ZT and increased the content of ABA in leaves, which is consistent with previous studies.

Changes in endogenous hormone levels in plants are related to physiology. For example, a large amount of ABA in a plant can cause the stomata of the plant to close, reduce transpiration, enhance the water retention capacity of leaves, improve the survival rate of the plant under stress, affect the contents of SOD, POD, MDA, soluble protein and soluble sugar, and reduce damage caused by drought or low-temperature stress [62,63]. The ABA content is different for different types of plants, and plants with strong cold resistance have a higher ABA content than plants with weak cold resistance. Moreover, studies have found that GA$_3$ content is related to plant cold resistance, plants with strong cold resistance have lower GA$_3$ levels, and plants with weak cold resistance have higher GA$_3$ content [64]. SOD, POD, MDA, soluble protein, and soluble sugar levels are widely considered to be related to cold and drought resistance. Furthermore, plant endogenous hormones dynamically change, and the content is different at different times and in different parts in different growth stages. Concurrently, there are complex antagonistic and promoting effects between...
different hormones that are affected by external conditions. The growth and development of plants are mainly affected by the synergistic effects of various hormones [58]. The changes in content of the four endogenous hormones in this experiment are consistent with the changes in morphological and physiological indicators of *M. wufengensis*. Therefore, it can be concluded that PGRs change the endogenous hormone level in *M. wufengensis* grafted seedlings, thereby changing the physiology and the consequent morphology and dwarfing the plant.

The seedlings used in this experiment were all 1-year-old grafted seedlings of *M. wufengensis* JiaoHong No. 2. The rootstock of the grafting seedlings was *Magnolia biondii* with the same two-year-old specification. It should be noted that grafting is also a dwarfing measure [9]. Although *M. biondii* is a tree, it exhibits a certain dwarfing effect as a *M. wufengensis* grafting rootstock. Therefore, according to the characteristics of graft dwarfing, *M. wufengensis* can choose appropriate rootstock grafting to achieve further dwarfing. Graft dwarfing has also been studied by researchers, and a dwarfing approach that is suitable for *M. wufengensis* will be found in the future. Judging from the current results, the dwarfing effect of PGRs is significant.

5. Conclusions

The optimal combination for dwarfing found in the PGR experiments was spraying 1500 ppm uniconazole five times. This treatment combination successfully dwarfed the grafted seedlings of *M. wufengensis* and enhanced its stress resistance. Uniconazole supplementation results showed that the optimal uniconazole concentration was 1500 ppm. When the uniconazole concentration was 2000 ppm or greater, the new leaves were deformed, and shrinkage or adhesion deformation occurred. Therefore, considering the morphological indicators and given that dwarfing is mainly performed for the ornamental value of *M. wufengensis*, the best measure for dwarfing *M. wufengensis* is to spray 1500 ppm uniconazole five times.

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**Data Availability Statement:** The data presented in this study are available on request from the corresponding author. The data are not publicly available due to ready to combine other data for further analysis and research.

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