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Exogenous Application of Thidiazuron, Carbaryl, Ethephon, and Lime Sulphur Promotes Flower Abscission and Suppresses Tea Pests in the Tea Plant *Camellia sinensis* (L.) O. Kuntze

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Abstract: Tea plants *Camellia sinensis* (L.) O. Kuntze consume substantial quantities of water and nutrients during the flowering period, which can adversely affect the yield and quality of tea plants. Therefore, the effects of thidiazuron, carbaryl, ethephon, and lime sulphur on flower buds and flower abscission in tea plants were investigated. The photosynthetic characteristics and biochemical components, the electrical conductivity of leaves, and the occurrence of insect pests and frost damage in the tea plants were assessed following the exogenous application of these chemicals. The results showed that 0.015, 0.03, and 0.06% thidiazuron, 0.08% ethephon, and 2.0 and 3.0% lime sulphur significantly promoted tea flower buds and flower abscission. Thidiazuron notably increased the concentrations of total amino acids, caffeine, catechin, and soluble sugar in tea leaves while reducing leaf electrical conductivity to some extent. Additionally, it also suppressed the occurrence of *Empoasca onukii* Matsuda (Hemiptera: Cicadellidae) and *Apolygus lucorum* Meyer-Dür (Hemiptera: Miridae). Furthermore, thidiazuron enhanced both the length and weight of tea shoots the following early spring. Application of 3.0% lime sulphur enhanced chlorophyll a and b, carotenoid, catechin, and caffeine and decreased the number of *Aleurocanthus spiniferus* Quaintanca (Hemiptera: Aleyrodidae) on the tea plants. However, no significant differences in frost damage were observed across treatments. Overall, exogenous application of the chemicals, particularly thidiazuron, effectively reduced flower production, altered key biochemical components, controlled tea pests, and ultimately enhanced tea productivity.

Keywords: tea plants; flower abscission; tea pests; thidiazuron; biochemical components

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1. Introduction

Tea plant (*Camellia sinesis* (L.) O. Kuntze) is a major economic crop in many countries, and tea, made from the tender shoots and leaves of tea plants, is one of the three most popular non-alcoholic drinks globally [1]. Tea plants blossom abundantly from September to December, with annual yields ranging from 3000 to 12,000 kg/hectare of tea plantations [2]. Flower buds and leaf buds coexist in the axils of the branches of tea plants. The germination and growth of leaf buds are inhibited when the flower buds in tea plants differentiate and develop. Large amounts of tea flowers and competition for nutrients between tea flowers and leaves may cause prominent competition between the vegetative and reproductive

growth of tea plants, which is not conducive to high yield or good quality of tea [3,4]. The removal of the flower buds and flowers from tea plants reduces the loss of nutrients that would otherwise be used for flowering and instead reallocates these nutrients to the growth of tea shoots and leaves, thereby increasing their yield and quality.

Various plant treatments, like plant growth regulators, serve multiple functions in controlling plant growth and development and their adaptation responses to environmental conditions. [5]. These treatments provide a wide array of capabilities for influencing plant growth and development. Research has demonstrated that these chemicals could expedite or postpone seed germination, alleviate dormancy in plants, spur or inhibit stem elongation, enhance or diminish flower and fruit production, and hasten or retard the aging process of plant organs [6,7]. Furthermore, the external application of these substances can enhance morphology, photosynthetic capacity, gas exchange parameters, enzyme activities, and other parameters, which in turn regulate the plant's various resistance to environmental stresses [8–10]. Specific aspects of the external application of these treatments to manipulate flowering processes in plants include delaying flower bud formation and flower opening, accelerating the senescence of petals, and stimulating the abscission of floral buds and open flowers [11–13]. In agricultural production, certain plant treatments, including plant growth regulators, are used to eliminate redundant flowers to ensure the quantity and quality of agricultural products [14]. Thidiazuron, carbaryl, ethephon, and lime sulphur were selected for this study due to their roles in tea production. Thidiazuron, a synthetic cytokinin, promotes cell division and is widely used to induce flowering in plants [15]. Carbaryl, an insecticide, controls pests and may indirectly influence flowering by alleviating stress [16]. Ethephon releases ethylene, which promotes flower abscission [17]. Lime sulphur, primarily a fungicide, also regulates growth and controls pests [18,19]. Although these compounds serve different primary functions, they are collectively employed in tea production to regulate flowering.

Although many studies have focused on chemical flower thinning in horticultural crops, few studies have investigated the effects of certain chemicals, including plant growth regulators, on both tea flower thinning and the overall growth and development of tea plants [20–22]. Consequently, this study assessed how varying concentrations of chemicals, including thidiazuron, carbaryl, ethephon, and lime sulphur, influenced tea flower and flower bud numbers, alongside some physiological and biochemical parameters of tea plants. The numbers of three main sucking insect pests of tea plants, including *Apolygus lucorum* (Hemiptera: Miridae), *Empoasca onukii* (Hemiptera: Cicadellidae), and *Aleurocanthus spiniferus* (Hemiptera: Aleyrodidae), were also investigated. This study also evaluated cell damage induced by treatments via electrical conductivity (EC) and assessed tea plant resistance to environmental stress. Additionally, following a natural frost event 50 days post-treatment, frost damage was assessed to explore the potential link between exogenous chemicals for tea management and enhanced frost tolerance.

2. Materials and Methods

2.1. Field Experiments and Surveys

The field study was carried out at the Tea Experimental Plantation in Feicheng County, Tai'an, Shandong Province (36.17° N, 116.49° E), featuring 10-year-old Fudingdabai tea trees. The start date of the experiment was 23 October 2022, when 50% of tea flowers were at bloom. Each tested compound at each concentration was administered through spraying in three distinct tea plots (5 × 5 m), and each plot as a separate replicate. The compounds under test were applied using a MATABI-16 universal knapsack sprayer (Matabi, Tarragona, Spain) with a pressure of 0.3 MPa, a cone nozzle, and a flow rate of 650 mL/min, delivering a spray volume of 675 L ha^{-1}. Ethephon (≥85.0%), thidiazuron (≥93.0%), and carbaryl

(≥98.0%) were obtained from Solarbio Science and Technology Co., (Beijing, China) and 45.0% lime sulphur was sourced from Wuhan Kemike Biomedical Technology Co., Ltd. (Wuhan, China). Each chemical was prepared by diluting them in water containing 1.0% alcohol to prepare different concentrations, without the use of any surface-active agent. Amounts of 0.015, 0.03, and 0.06% (*w*/*v*) thidiazuron, 0.04, 0.06, and 0.08% carbaryl, 0.08 and 0.12% (*w*/*v*) ethephon, and 2.0 and 3.0% (*w*/*v*) lime sulphur were applied. The selection of these concentrations was based on commonly used effective concentration ranges reported in the literature and further adjusted based on preliminary experiments [23–26]. These concentrations effectively induced the desired responses in the tea tree. Water containing 1.0% alcohol served as the control treatment.

Examination of the quantity of tea flower buds and flowers, measurement of physiological and biochemical parameters, and examination of the occurrences of *A. lucorum*, *E. onukii*, and *A. spiniferus* were recorded 10 days after the chemicals were applied on the tea plants. Tea flower counts were recorded for each subplot (1 × 1 m) within the plot. To evaluate the efficacy of chemical agents in controlling pests on tea plants, a 25 × 20 cm yellow sticky trap (Zhangzhou Enjoy Agriculture Technology Co., Ltd., Zhangzhou, China) method was employed. The numbers of *A. lucorum*, *E. onukii*, and *A. spiniferus* in tea fields, sprayed within the past ten days, were measured during peak pest periods. On November 12, 2022, 50 days after the treatment, the occurrence of frost damage to tea plant leaves in 1 × 1 m subplots was recorded within each plot, following a natural frost event. Frost damage was rated on a scale of 0 to 5: 0 = no frost damage, 1 = frost damage on <20% of the leaf, 2 = 21–50% of the leaf damaged, 3 = 51–75% of the leaf damaged, 4 = 76–90% of the leaf damaged, and 5 = frost damage on > 90% of the leaf. Frost damage severity was calculated using the formula = [Σ (number of frost-damaged leaves in each subplot × rating)/(total number of tea leaves × 5)] × 100.

On May 13, 2023, during the following spring, tea shoot counts were conducted in the 1 × 1 m subplots, and the length and weight of two leaves, as well as the average length and weight of shoots containing two leaves and one bud, were recorded as averages for each plot.

2.2. Determination of Electrical Conductivity

The third to fifth functional leaves of the same size from the current year's branches were collected randomly at random points for measurement. To maintain the condition of the tea leaves, only portions of the minimal stem nodes were preserved during collection. The leaves underwent washing with tap water, followed by three rinses with distilled water, and they were blotted with filter paper. Long strips of leaves, with the main veins removed, were cut to suitable lengths and quickly separated into three equal portions of 0.1 g. The leaf sample (0.1 g) was transferred to a 50 mL centrifuge tube with 10 mL of deionized water, covered with a stopper, and placed at room temperature for 12 h to incubate, with shaking 3–4 times throughout the period. The conductance of the extract was determined using an electrical conductivity meter (DDS-11A, INESA, Shanghai, China) and recorded as S1. The extract was subsequently transferred to a 100 °C water bath for 30 min, followed by gradual cooling to room temperature. The extract was re-measured for conductance, and the obtained value was labeled as S2. The conductivity value of double-distilled water was designated as S0. The electrical conductivity of tea leaves was calculated according to the equation electrical conductivity = (S1 − S0)/(S2 − S0) ×100%.

2.3. Determination of Photosynthetic Pigment Contents

Pigment extracts were produced by grinding 0.2 g of fresh leaves (third leaf from each branch) in 60 mL of 80% acetone and incubating the mixture in the dark for 36 h, using a tissue

homogenizer, until the leaves became completely colorless. A spectrophotometer (UV-2450, Shimadzu, Kyoto, Japan) was employed to measure absorbance at three wavelengths of 663, 646, and 470 nm and to determine the concentrations of chlorophyll a and b and carotenoid. Chlorophyll a, chlorophyll b, and carotenoid concentrations were calculated according to the following equations: $C_{chl.\ a}$ (mg g^{-1} FW) = $(OD_{663} \times 12.21 - OD_{646} \times 2.81)/(W \times 1000) \times V$; $C_{chl.\ b}$ (mg g^{-1} FW) = $(OD_{646} \times 20.13 - OD_{663} \times 5.03)/(W \times 1000) \times V$; $C_{car.}$ (mg g^{-1} FW) = $(OD_{470} \times 1000 - C_{chl.\ a} \times 3.27 - C_{chl.\ b} \times 104)/(W \times 229 \times 1000) \times V$ [27]. In this equation, V represents the volume of the extract (in mL), and the fresh weight (FW) of the leaf sample (in grams) is represented by W; OD_{470}, OD_{646}, and OD_{663} correspond to the absorbance at 470, 646, and 663 nm.

2.4. Determination of Leaf Chlorophyll Fluorescence

Chlorophyll fluorescence was quantified with a modulation-based fluorescence analyzer (Hansatech, King's Lynn, Norfolk, UK). Nine replicates were used to measure the third leaf from various tea shoots with comparable light orientations. Prior to measurement, the tea leaves were covered for approximately 20 min using specially designed clips. Following dark acclimation, a high-intensity light pulse (PPFD = 3000 μmol $m^{-2}s^{-1}$) was introduced to assess the maximum fluorescence (Fm). Subsequently, actinic light at a PPFD of 1200 μmol m^{-2} s^{-1}, sufficient to drive photosynthesis, was applied for 30 min. The actual photochemical efficiency of photosystem II (Φ_{PSII}) and the maximum fluorescence under steady-state conditions ($F'm$) were measured by applying saturated white light pulses every 1 min, with the actinic light remaining on throughout. The non-photochemical quenching (NPQ) was determined using the equation $NPQ = (Fm - F'm)/F'm$.

2.5. Determination of Biochemical Components

Amino acids, tea polyphenols, caffeine, and soluble sugars in tea shoots with two leaves and one bud were quantified using five replicates, following the methodology of Tian et al. [25]. Fresh tea shoots underwent heating in a microwave oven for 70 s, followed by drying at 80 °C for about 6 h, and they were subsequently ground into a fine powder. Samples of dried tea leaf were kept at −20 °C until the biochemical components were measured.

Free amino acid content was assessed through the ninhydrin colorimetric method. A 3 g portion of dried leaf sample was placed into a flask, which was then filled with 450 mL of deionized water. The mixture underwent extraction for 45 min in a boiling water bath, after which it was filtered while still hot. The filtrate volume was adjusted to 500 mL by adding H_2O. A 1 mL aliquot of the diluted filtrate was transferred to a 25 mL volumetric flask containing 0.5 mL of 2% ninhydrin solution (prepared by dissolving 80 mg of $SnCl_2$-$2H_2O$ and 2 g of ninhydrin dissolved in 100 mL of H_2O) and 0.5 mL of buffer (composed of 3 mM of KH_2PO_4 and 63 mM of Na_2HPO_4, pH 8.0). Following 15 min of incubation in a boiling water bath, the solution was diluted to a final volume of 25 mL by adding water. Following a 10 min settling period, the absorbance of the solution at 570 nm was determined by using a spectrophotometer (UV-2450, Shimadzu, Japan). A standard curve constructed with different concentrations of glutamine was used to calculate the free amino acid content.

Catechins were quantified using the vanillin colorimetric method. The dried leaf sample (1 g) was placed in a 100 mL conical flask containing 20 mL of 95% ethyl alcohol and heated under reflux at 80 °C for 30 min. After filtration, the filtered extract was then adjusted to 25 mL with 95% ethyl alcohol as the solvent. A 20 μL aliquot of the filtrate was mixed with 1 mL of 95% ethyl alcohol and 5 mL of a vanillin hydrochloric acid reagent (1 g of vanillin in 100 mL of concentrated HCl) in a 20 mL test tube. After 40 min, the absorbance

at 500 nm was recorded spectrophotometrically (UV-2450, Shimadzu, Japan). A standard curve created with catechin dilutions was used to measure the catechin concentration.

Tea polyphenol content was quantified by using the Folin–Ciocalteu reagent method. First, 200 mg of dried tea leaf sample was placed in a 10 mL centrifuge tube, and 5 mL of 70% methanol was added at a temperature of 70 °C. The mixture underwent extraction in a 70 °C water bath for 10 min, followed by centrifugation at 3500 rpm for 10 min. A 1.0 mL aliquot of the supernatant was then transferred to a 10 mL volumetric flask. The volumetric flask received 5 mL of 10% Folin–Ciocalteu reagent, followed by the addition of 4 mL of 7.5% Na_2CO_3 after 5 min. After a period of 10 min for settling, the solution was analyzed at an absorbance of 765 nm spectrophotometrically. Tea polyphenols were quantified using a standard curve derived from gallic acid dilution series.

The basic lead acetate reagent method was used to determine the caffeine content. A 3 g sample of dried tea leaf was extracted in 450 mL of H_2O and extracted in a boiling water bath for 45 min, with shaking intervals of 10 min. The filtrate was adjusted to a final volume of 500 mL with the addition of H_2O in the 500 mL volumetric flask after filtration. In a 100 mL centrifuge tube, 10 mL of the diluted filtrate was mixed with 1 mL of 0.5 g mL^{-1} lead subacetate and 4 mL of 0.01 mol L^{-1} hydrochloric acid. The solution was diluted to a final volume of 100 mL with water. Following a 30 min settling period, 25 mL of the supernatant was placed in a 50 mL flat-bottom flask, to which 100 µL of 4.5 mol L^{-1} sulfuric acid solution was added, and the volume was then brought to 25 mL with water. Absorbance values of the extract at 274 nm were determined spectrophotometrically. A standard curve, prepared from a range of caffeine concentrations, was used to determine the caffeine content.

Anthrone colorimetry was employed to measure the soluble sugar levels. The dried tea leaf sample (1 g) was extracted with 80 mL of H_2O. The mixture underwent extraction in a boiling water bath for 45 min and was subsequently filtered while hot. To reach a final volume of 500 mL, water was added to the filtrate. To the mixture, 1 mL of anthrone reagent was added, followed by the addition of 8 mL of the reagent. The mixture's absorbance was determined at 620 nm using the spectrophotometer.

2.6. Statistical Analysis

Statistical analysis of the data was carried out using Microsoft Excel software (Version, 2017) and SPSS (Version 20.0, SPSS Inc., Chicago, IL, USA). One-way ANOVA was used for statistical analysis, with applied Tukey's HSD test ($p < 0.05$) for comparisons. Prior to analysis, the tea flower thinning rate, electrical conductivity, biochemical component content, number of insect pests, and frost damage severity underwent transformation using the arcsine square root method, with the untransformed data presented for reference.

3. Results

3.1. Effects of Chemicals on Tea Flower Abscission and Electrical Conductivity

The 0.015, 0.03, and 0.06% thidiazuron significantly reduced the number of tea flowers, with reductions of 52.13, 69.63, and 52.24%, respectively ($F = 4.74$, $p = 0.008$). The 2.0% lime sulphur also resulted in a significant decline in the number of tea flowers, with a 68.21% reduction. No significant differences were observed in the reduction rates of tea flower between the carbaryl- and ethephon-treated tea plants and the untreated control. No significant differences in the electrical conductivity of tea leaves were found among the chemically treated tea plants and the untreated controls, except for the tea plant leaves treated with 0.015% thidiazuron ($F = 3.050$, $p = 0.014$) (Figure 1).

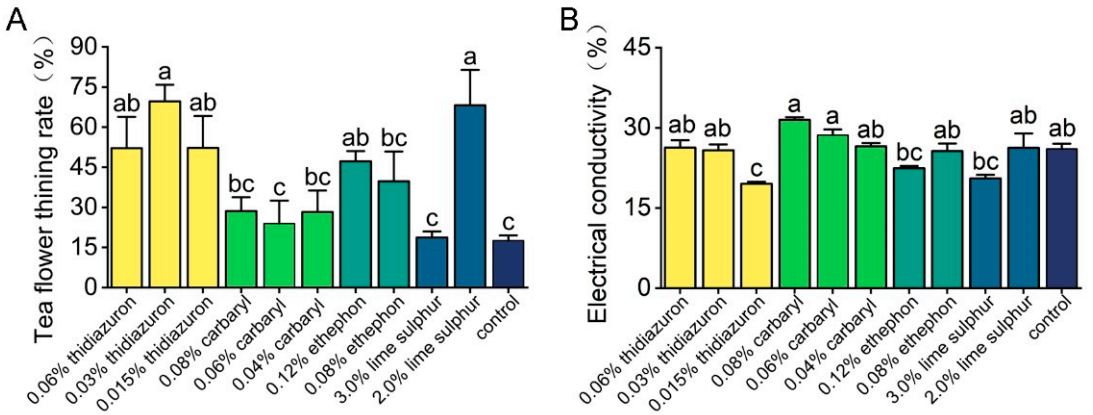

Figure 1. Effects of thidiazuron, carbaryl, ethephon, and lime sulphur on the number of tea flower buds and flowers in the tea plantations (**A**) and the electrical conductivity of tea leaves (**B**). Different letters indicate significant differences between the different treatments (Tukey's HSD test, $p < 0.05$). Data are means of three independent plots ± SE.

3.2. Effects of Chemicals on Pigments and Photosynthetic Characteristics

The chlorophyll a, chlorophyll b, and carotenoid levels in the tea leaves treated with 3.0% lime sulphur were significantly higher compared to the untreated control tea leaves (chlorophyll a: $F = 3.992$, $p = 0.003$; chlorophyll b: $F = 2.844$, $p = 0.002$; carotenoid: $F = 3.992$, $p = 0.003$). No significant differences in the contents of photosynthetic pigments were found among other different chemical treatments. Tea leaves treated with 0.015% thidiazuron showed significantly higher Φ_{PSII} than that in the untreated control tea leaves. The 0.08% ethephon significantly reduced Φ_{PSII} in the tea plant leaves ($F = 10.741$, $p < 0.001$). Also, the 0.08% carbaryl significantly reduced Fv/Fm in the tea plant leaves ($F = 4.197$, $p < 0.001$). No significant differences in Φ_{PSII}, Fv/Fm, or NPQ were observed among the other different chemical treatments (Figure 2).

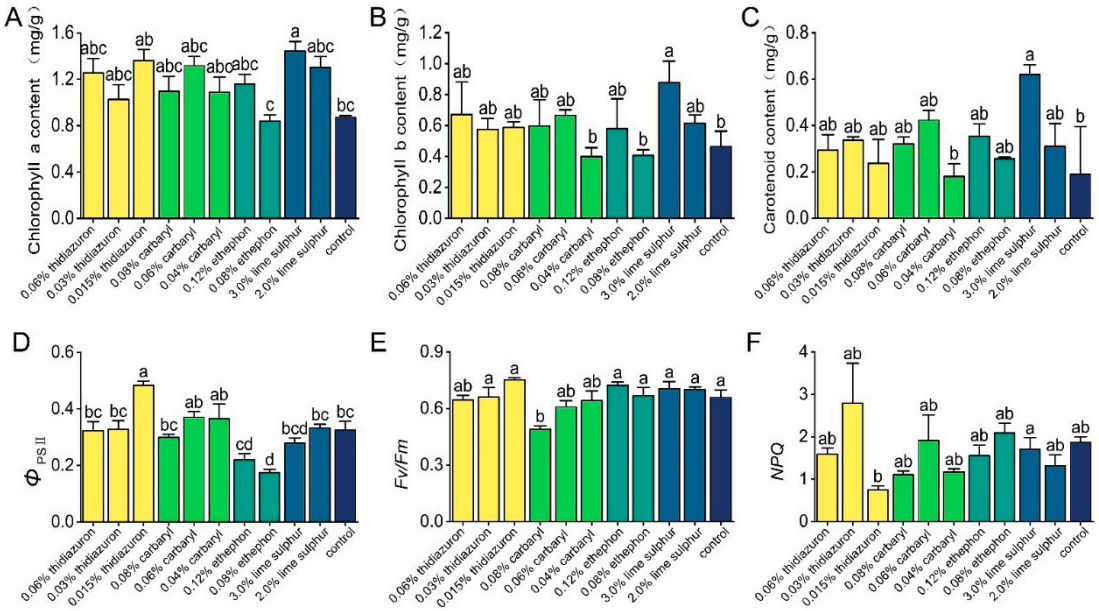

Figure 2. Effects of thidiazuron, carbaryl, ethephon, and lime sulphur on the chlorophyll a (**A**), chlorophyll b (**B**), and carotenoid (**C**) concentrations in tea plant and the photosynthesis indicators of the tea plants, including the PSII actual photochemical efficiency (Φ_{PSII}) (**D**), maximum quantum yield of photosystem II (Fv/Fm) (**E**), and non-photochemical quenching (NPQ) (**F**). Different letters indicate significant differences between the different treatments (Tukey's HSD test, $p < 0.05$). Data are means of three independent plots ± SE.

3.3. Effects of Chemicals on Biochemical Components

The 0.03 and 0.06% thidiazuron significantly increased the total amino acids and caffeine content in the tea plant leaves, respectively (total amino acids: $F = 8.981$, $p < 0.001$; caffeine: $F = 5.598$, $p < 0.001$). The 0.08 and 0.12% ethephon and 2.0% lime sulphur significantly reduced the content of tea polyphenol in the tea plant leaves ($F = 8.355$, $p < 0.001$). Tea leaves treated with 0.03% and 0.06% thidiazuron and 2.0% lime sulphur exhibited significantly higher catechin levels compared to the untreated control leaves. ($F = 15.637$, $p < 0.001$). The 0.06% thidiazuron, 0.04 and 0.08% carbaryl, and 0.12% ethephon significantly increased the soluble sugar content of tea plant leaves ($F = 4.051$, $p = 0.003$) (Figure 3).

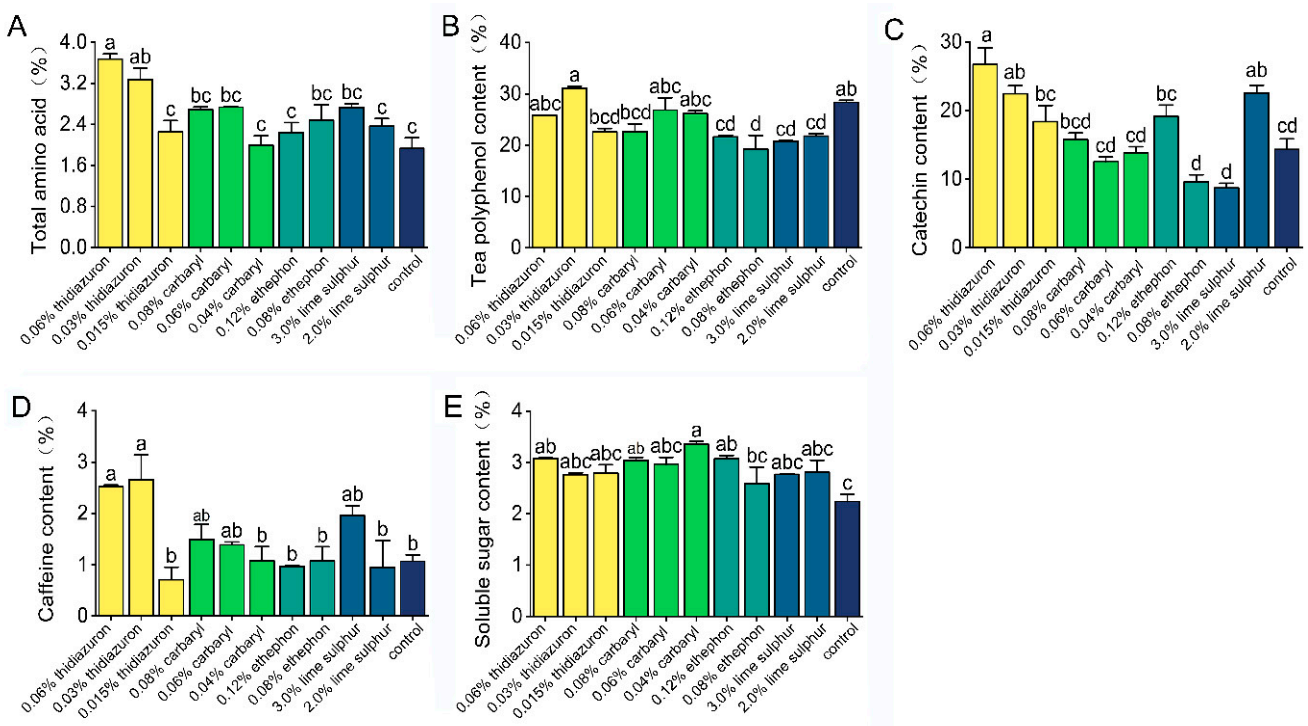

Figure 3. Effects of thidiazuron, carbaryl, ethephon, and lime sulphur on the content of total amino acid (**A**), tea polyphenol (**B**), catechins (**C**), caffeine (**D**), and soluble sugar (**E**) on the tea plant. Different letters indicate significant differences between the different treatments (Tukey's HSD test, $p < 0.05$). Data are means of three independent plots ± SE.

3.4. Effects of Chemicals on Insect Pests and Frost Damage on Tea Plants

Tea plants treated with thidiazuron, carbaryl, ethephon, and 2.0% lime sulphur had significantly fewer *A. lucorum* compared to the untreated control plants ($F = 4.170$, $p < 0.001$). Tea plants treated with 0.08% ethephon and 3.0% lime sulphur had significantly fewer *A. spiniferus* compared to untreated plant ($F = 9.06$, $p < 0.001$). The 0.015 and 0.06% thidiazuron significantly reduced the number of *E. onukii* on the tea plants ($F = 11.549$, $p < 0.001$). Lime sulphur treatment reduced frost damage on tea plants compared to untreated plants, although no statistically significant effects were observed ($F = 2.816$, $p = 0.007$) (Figure 4).

3.5. Effects of Chemicals on Tea Shoots the Following Spring

None of the four tested chemicals had a notable effect on the tea shoot count the following spring. In contrast, 0.015, 0.03, and 0.06% thidiazuron significantly promoted the length and weight of tea shoots (length: $F = 15.161$, $p < 0.001$; weight: $F = 13.126$, $p < 0.001$). No significant differences in the tea shoot length and weight were observed among other different chemical treatments (Figure 5).

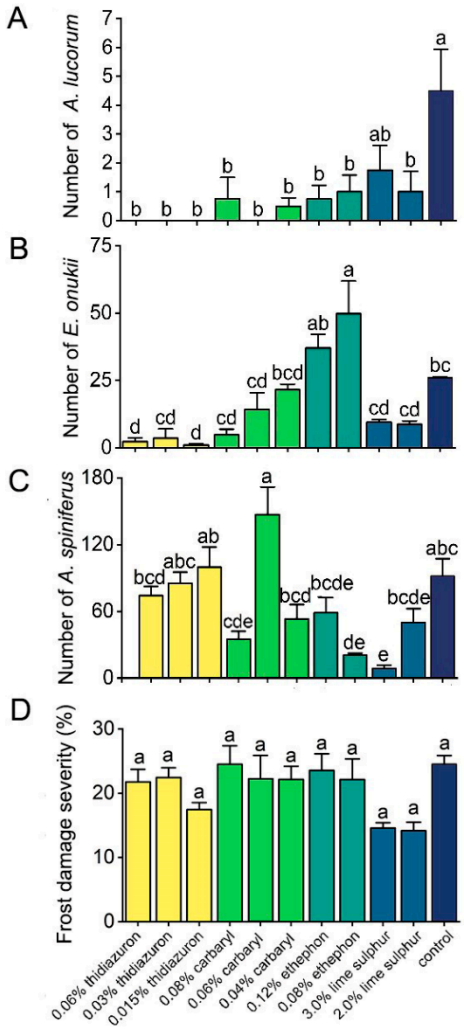

Figure 4. Effects of thidiazuron, carbaryl, ethephon, and lime sulphur on the number of *A. lucorum* (**A**), *E. onukii* (**B**), and *A. spiniferus* (**C**) on the traps next to the tea plant. Traps were installed immediately after spraying and measured 10 days following treatment. The frost damage severity (**D**) on the tea plant was also measured. Different letters indicate significant differences between the different treatments (Tukey's HSD test, $p < 0.05$). Data are means of three independent plots ± SE.

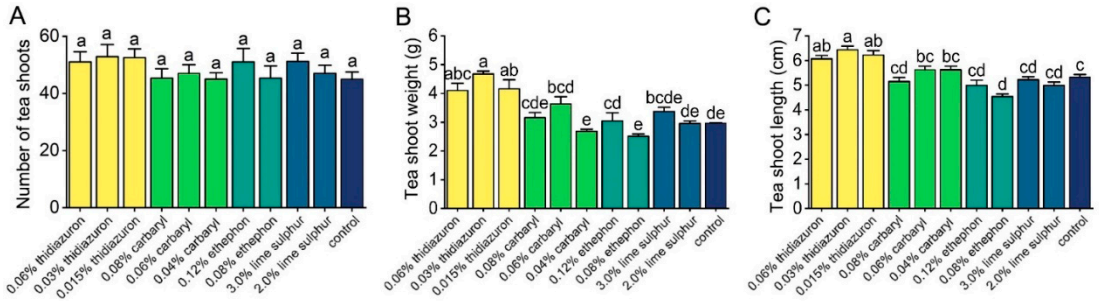

Figure 5. Effects of thidiazuron, carbaryl, ethephon, and lime sulphur on the number of tea shoots (**A**) as well as on the tea shoot weight (**B**) and length (**C**). Different letters indicate significant differences between the different treatments (Tukey's HSD test, $p < 0.05$). Data are means of three independent plots ± SE.

4. Discussion

The application of thidiazuron facilitated tea flower abscission in tea plantations. Although few studies have explored thidiazuron-induced flower shedding, numerous studies have found that thidiazuron-induced leaf shedding was associated with increased

endogenous ethylene levels, abscisic acid (ABA) accumulation, and reduced endogenous indole-3-acetic acid (IAA) levels in the treated leaves and shed areas [28,29]. Therefore, we hypothesized that thidiazuron-mediated shedding of tea flowers may be related to its coordination with the synthesis, metabolism, and transportation of the endogenous hormones ethylene, IAA, and ABA. Although thidiazuron had little impact on the count of tea shoots, this compound significantly increased the tea shoot length and weight the subsequent spring. Under certain concentrations of thidiazuron treatment, many plants showed strong growth and development ability [30]. The elongation and weight gain of branches may also be related to the influence of thidiazuron on the levels of endogenous plant hormones and the interaction with endogenous plant hormones, such as ethylene, gibberellic acid, trans-zeatin-riboside, and IAA [31,32].

Plant cell membranes are crucial for maintaining the cell's microenvironment and normal metabolism [12,33]. Under normal conditions, plant cell membranes have the ability to determine the permeation of substances. When a plant is exposed to an adverse environment, its cell membrane becomes compromised, leading to increased membrane permeability. This results in the extravasation of intracellular electrolytes, thereby increasing the electrical conductivity of the cell extract [34,35]. The increase in membrane permeability correlates with the severity of stress and the plant's resistance to environmental challenges [36]. Therefore, electrical conductivity studies have become an accurate and practical method for identifying the resistance of plants to stress. In this study, the almost unchanged electrical conductivity indicated that tea leaves treated with different tested chemicals were under similar environmental stress. The slightly decreased frost damage might be associated with the lower electrical conductivity of the tea leaves treated with thidiazuron at low concentrations. Some studies showed that thidiazuron could enhance the plant's ability to adapt to stress [37,38].

Previous studies have shown that thidiazuron could significantly increase the contents of biochemical components in plant leaves [39,40]. Tea plants are abundant in various biochemical components and secondary metabolites, which provide a unique taste and have a variety of nutritional and healthy functions [9,41,42]. The results indicated that thidiazuron also increased the contents of amino acids, catechins, caffeine, and soluble sugar to a certain extent. This effect is likely due to thidiazuron's influence on the secondary and nitrogen metabolism of tea plants, which in turn affects the levels of these key biochemical components. Catechins and caffeine have been recognized as crucial compounds that improve the resistance of tea plants to insect pests [43,44]. The population densities of *A. lucorum* and *E. onukii* were notably influenced by the exogenous application of thidiazuron. Low population densities of tea pests on the thidiazuron-treated tea plants might be attributed to very high contents of catechins and caffeine in the tea leaves. Moreover, the increase in the contents of amino acids, catechins, caffeine, and soluble sugar in fresh tea leaves could improve the organoleptic evaluation quality of brewed tea [45,46].

Lime sulphur is commonly used for protecting tea plants from frost in winter in Chinese tea plantations [47]. Our studies showed that lime sulphur at high concentrations significantly regulated the abscission of tea flowers. Some studies have indicated that lower concentrations of lime sulphur had a flower thinning effect by inhibiting pollen tube growth [18,48]. In addition, lime sulphur at × 1.0 significantly increase tea leaf photosynthetic pigment contents, which could be beneficial for the cold resistance of the tea plants. We hypothesized that an increase in photosynthetic pigments would increase photosynthesis in the tea plants, leading to the accumulation of glucose and other carbohydrates in the tea plant cells associated with cold tolerance [49]. As an insecticide, lime sulphur is effective at controlling various injurious insects, such as the Hemiptera, Cryptoptera, and injurious mites [50–53]. Lime sulphur reduced the numbers of *A. spiniferus*, *A. lucorµm*,

and *E. onukii* on the tea plants when tea pest populations peaked in autumn, which was also due to the changes in the biochemical components of tea plants, such as catechins and caffeine.

The application of 0.12% ethephon can promote flower shedding to a certain extent. The external application externally enhances the synthesis of endogenous ethylene, which in turn triggers ethylene-induced flower abscission [54,55]. After ethephon treatment, the large central vacuoles and other organelles in the flower cells were substantially damaged, many petal cells were distorted and broken down due to the loss of cytoplasm, and two types of programmed cell death (including nuclear shrinkage and DNA fragmentation) happened [56]. Then, the petals of tea flowers senesced, rapidly browned, and partially withered [57]. Ethylene triggers the expression of genes in the biosynthesis and signaling pathways, which ultimately promote flower abscission [58,59]. Tian et al. [25] found that the influence of ethephon on flower abscission correlates with the expression of genes involved in ethylene signaling, such as 1-aminocyclopropane-1-carboxylic acid synthase and ethylene receptors.

5. Conclusions

In conclusion, thidiazuron had varying degrees of influence on tea flower abscission and promoted the growth of the tea shoots by increasing their length and weight. Simultaneous with the flower thinning effect, thidiazuron could change the tea leaf compounds and conductivity and further influence the occurrence of *A. spiniferus* and *E. onukii*. Lime sulphur at high concentrations promoted tea flower abscission and reduced the number of three tea insect pests on the tea plants. The results will help to understand the impact of exogenous application of some chemicals on flower abscission as well as the growth and protection of tea plants, particularly in autumn and winter.

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