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Desuckering effect of KH_2PO_4 mixed with paclobutrazol and its influence on banana (*Musa paradisiaca* AA) mother plant growth

Li-Na Luo[a,b], Li Cui-Ling[a], Fan Wu[a], Shao-Peng Li[a], Shu-Quan Han[b], Mao-Fu Li[a,*]

[a] College of Tropical Agriculture and Forestry, Hainan University, Haikou, 570228, Hainan, China
[b] Institute of Subtropical Crops, Guizhou Academy of Agricultural Sciences, Xingyi, 562400, Guizhou, China

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ABSTRACT

This study investigated the desuckering effect of a 2:1 mixture of KH_2PO_4 (KDP) and paclobutrazol (PBZ) and its influence on banana mother plant growth, fruit yield, and quality. The mixed reagent was injected into suckers sprouting from 5-month-old banana (*Musa paradisiaca* AA) plants after removing the above-ground part of the suckers. Compared to control plants, treatment with the KDP/PBZ mixture significantly reduced superoxide dismutase, peroxidase, and catalase activities but increased malondialdehyde content at sucker growth points and in adjacent tissue after 1 d. There was evidence of damage to the cellular structure at sucker growth points after 2 d of treatment, with an increase in intercellular space as well as rupturing and death of most cells. All suckers died 3 d later, resulting in a mortality rate of up to 100%, and there was no subsequent regrowth of the dead suckers; indicating that a single application of the KDP/PBZ reagent is a viable desuckering practice. Relative to the control, the treatment of suckers also indirectly increased the height and stem diameter of mother plants, which was associated with increased fruit yield (yield per plant, weight per hand, weight per fruit, transverse and longitudinal diameters of fruit fingers) and enhanced nutritional quality of the fruits (edible fraction, soluble solid, titratable acidity, vitamin C, and moisture content). These results indicate that a 2:1 KDP/PBZ mixture can effectively remove banana suckers while improving fruit yield and the quality of the mother plant. The proposed desuckering practice can help to address challenges associated with banana production such as difficulties in desuckering and preventing sucker regrowth, minimizing fertilizer waste, and high costs.

1. Introduction

The banana is an evergreen perennial belonging to the genus *Musa* L. in the family Musaceae. This fruit crop originated in Southeastern Asia, and it primarily grows in tropical and subtropical regions. Nowadays, the banana is extensively cultivated in more than 130 countries worldwide. Globally, the banana is regarded as one of the world's four major fruits, along with oranges, grapes, and apples, besides, it is the fourth major food crop after rice, wheat, and corn (Li et al., 2008).Owing to the fruit being sweet, flavourful, and containing high nutrient levels, bananas are favoured by most consumers, resulting it being the most traded (in terms of volume) fresh fruit worldwide (Yuan et al., 2012).

The banana plant grows most vigorously in tropical regions with high rainfall (Li, 2012). When the banana plant grows to a certain size, many suckers, that are derived from axillary buds, sprout from the rhizome (also known as the corm) of the mother plant (6–8 suckers per plant). The suckers consume nutrients; reduce growth vigour; and delay budding, blooming, and fruiting of the mother plant, which undermines fruit yield and fruit quality (Chundawat and Patel, 1992). A previous study showed that banana yield was reduced by 7.9%–17.5% if the suckers were not removed in a timely manner (Robinson and Nel, 1986). Additionally, excessive sucker growth can affect ventilation and light transmission in a banana plantation, thereby increasing air humidity and the subsequent prevalence of plant diseases and pests (Ouyang and Chen, 1999). For these reasons, a single sucker is selected and retained after the onset of flowering in most banana cultivation and management strategies, and the remaining suckers are promptly removed (a process known as desuckering) to achieve a high yield of superior-quality banana fruits.

To date, only a few studies have investigated banana desuckering techniques in detail (Xie et al., 1999; Lv, 2001; Ruan, 1998) and,

Abbreviations: KDP, KH_2PO_4, Potassium dihydrogen phosphate; PBZ, paclobutrazol; CAT, catalase; MDA, malondialdehyde; NBT, nitroblue tetrazolium; POD, peroxidase; SOD, superoxide dismutase; TBA, thiobarbituric acid; Vc, vitamin C; H, 2:1 mixture of KH_2PO_4 and paclobutrazol; CK, No reagent

* Corresponding author.
E-mail addresses: 125893926@qq.com (L.-N. Luo), licl2001@163.com (C.-L. Li), 1579701323@qq.com (F. Wu), Lisp13648661389@163.com (S.-P. Li), hanshuquan@163.com (S.-Q. Han), Hafu98022@126.com (M.-F. Li).

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therefore, information on the most effective approaches is lacking. Suckers are typically removed by one of two methods: (1) physical or manual desuckering, whereby the sucker growth points are damaged (e.g. using a shovel), the suckers are cut off at ground level (e.g. using a knife), or the sucker pseudostem is excavated (e.g. using a hoe) (Chen, 2010). These approaches are time-consuming and labour-intensive and if not performed carefully, can damage the corm and roots of the mother plant. (2) Chemical desuckering uses chemicals to destroy or inhibit the growth of suckers. Various reagents have been employed for this purpose, including diesel (Ruan, 1998), kerosene (Lin, 1997), diluted glyphosate (Xu and Huang, 2000), and 2,4-dichlorophenoxyacetic acid (Chundawat and Patel, 1992). However, these chemicals have variable effects, cause environmental pollution, and can be harmful to the mother plant.

Paclobutrazol (PBZ) is a triazole plant growth regulator developed in the 1980 s (Huang et al., 2011) that has been shown to inhibit plant cell division and elongation by suppressing the production of gibberellin derivatives. Paclobutrazol (PBZ)is often used to delay plant growth, inhibit stem elongation, shorten internodes, and promote flowering and fruit setting in horticultural crops (Sui and Zhang, 2006; Wang, 2009). Potassium dihydrogen phosphate (KH_2PO_4, KDP) is a commonly used foliar fertilizer (Xu, 2010) that can improve plant yield and quality, increase disease and pest resistance, and prevent lodging. KDP has advantages over conventional fertilizers, including a lower dosage requirement, ease of absorption, low cost, and low toxicity in agricultural production (Li, 2010; Xu, 2009).

We previously compared the desuckering efficacy of KDP, PBZ, pendimethalin oil, and other reagents (Luo et al., 2016). In the present study, we investigated whether a mixture of KDP and PBZ is effective for desuckering *Musa x paradisiaca* (*Musa* AA) and evaluated the influence of the reagent on mother plant growth, fruit yield, and quality. The aim of the study was to develop an efficient, safe, and cost-effective desuckering strategy for banana plants that would reduce fertilizer wastage and enhance fruit production.

2. Materials and methods

2.1. Material treatment and experimental design

This study was conducted from December 2014 to August 2017 in a banana plantation in Qiaotou Town, Chengmai County, Hainan Province, China. Five-month-old banana mother plants of *Musa* x *paradisiaca* (*Musa* AA)and their sprouting suckers were used as the experimental materials. The mother plants were similar in size, showed robust growth, had no diseases or pests, and harboured a comparable number of suckers.

A banana knife was used to cut off the pseudostems of the suckers at the ground level. A custom-designed chemical desuckering device for bananas was used to inject 3 g of the 2:1 KDP/PBZ mixture into the suckers along the central part of their transverse plane. As a control, the pseudostems of the suckers were cut off but no reagent was injected (No diesel, kerosene diluted glyphosate, 2,4-dichlorophenoxyacetic acid as a control, these chemicals cause environmental pollution). Each treatment group consisted of five mother plants with three replicates. During the experimental period, all suckers sprouting from a mother plant were injected with the KDP/PBZ mixture and 1 d later, another five suckers from each treatment group were randomly selected for measurement of biochemical parameters including superoxide dismutase (SOD), peroxidase (POD), and catalase (CAT) activities and malondialdehyde (MDA) content. Two days after injection, five random suckers were selected from each treatment group for examination of tissue structure changes at the growth point. After 3 d, the number of viable suckers was counted to calculate the mortality rate, and the external morphology of sucker roots from each treatment was evaluated in longitudinal sections by microscopy. Growth indicators of the mother plant including stem diameter and height were measured every 15 d after injection until flower buds stage was observed. Fruit yield and quality were determined after harvesting.

2.2. Measurement indicators and methods

2.2.1. Analysis of SOD, POD, and CAT activities and MDA content

2.2.1.1. Enzyme extraction. Five random suckers were selected from each treatment group for determination of SOD, POD, and CAT activities as well as MDA content as previously described (Lu and Li, 2012; Wang, 2006), with slight modifications. Briefly, 0.5 *g* of a sucker growth point was accurately weighed into a mortar pre-cooled to 4 °C A 1 ml volume of 50 mmol·l^{-1} Na_2HPO_4–NaH_2PO_4 buffer solution (pH 7.8) pre-cooled to 4 °C was added to the mortar, and the sample was ground at a low temperature. The homogenate was transferred to centrifuge tubes. The mortar was rinsed with 3 ml Na_2HPO_4–NaH_2PO_4 buffer solution and the solution was combined with the supernatant. The extract was centrifuged at 4 °C and 10 000 r·min^{-1} for 20 min, and the supernatant was used as the crude enzyme solution.

2.2.1.2. SOD activity. SOD activity was analysed using the nitroblue tetrazolium (NBT) reduction test. The following components were sequentially added to the enzyme reaction mixture: 1.5 ml of 50 mmol·l^{-1} Na_2HPO_4–NaH_2PO_4 buffer solution (pH 7.8), 0.3 ml of 130 mmol·l^{-1} methionine solution, 0.3 ml of 750 μmol·l^{-1} NBT solution, 0.1 ml enzyme solution, and 0.2 ml distilled water. The reaction was thoroughly mixed in a 20 ml glass test tube and then allowed to react under 4000 lx illumination for 8 min. Two test tubes were set up as the controls in which the enzyme solution was substituted with distilled water. After mixing, one control tube was placed in the dark while the other was reacted along with the sample tubes containing enzyme solution under fluorescent light for 8 min. The tubes were immediately moved to the dark after completion of the reaction. A control tube incubated in the dark served as a blank reference. The absorbance of the solutions was measured at 560 nm. One unit of SOD activity was defined as the amount of enzyme that caused 50% inhibition of the photochemical reduction of NBT in the reaction system per g (fresh weight) of plant material per min.

2.2.1.3. POD activity. POD activity was analysed based on guaiacol oxidation. The following components were sequentially added to the enzyme reaction mixture: 3 ml of 25 mmol·l^{-1} guaiacol solution, 0.2 ml of 250 mmol·l^{-1} hydrogen peroxide solution, and 0.1 ml enzyme solution. The absorbance of the reaction at 470 nm was recorded at 30 s intervals, starting 30 s after the addition of enzyme solution and continuing for 5 min. One unit of POD activity was defined as the amount of enzyme that caused an increase of 0.001 in the absorbance at 470 nm per min per g (fresh weight) of plant material.

2.2.1.4. CAT activity. A 3 ml volume of a 20 mmol·l^{-1} hydrogen peroxide solution was added to 10 ml test tubes; 50 μl crude enzyme solution was then added, and the mixture was immediately mixed and transferred into a quartz cuvette for continuous measurement of the absorbance at 240 nm for 3 min. Initial and final absorbance were recorded. One unit of CAT activity was defined as the amount of enzyme that caused a change of 0.001 in the absorbance at 240 nm per min per g (fresh weight) of plant material.

2.2.1.5. MDA content. MDA content was analysed with a colorimetric assay using thiobarbituric acid (TBA) as follows: 0.5 *g* of sucker growth point was accurately weighed and ground with 8 ml of 10% trichloroacetic acid. The homogenate was transferred to 10 ml centrifuge tubes and centrifuged at 4000 rpm for 10 min. The supernatant was collected as the MDA extract. A 2 ml volume of 0.6% TBA solution was added to each of the three replicate sample tubes (with 2 ml of MDA extract) and one control tube (with 2 ml distilled water) and was mixed by shaking. The mixture was allowed to react in a