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Original Research Article

Residue Content of Sugarcane Ripener Active Ingredients and Its Effect on Ratoon's Growth in North Sumatera

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ABSTRACT

The degree of sugarcane ripening is a vital parameter determined by measuring sucrose accumulation in sugarcane stalks. The constraints related to the degree of maturity that affect the quality of sugarcane in milled raw materials can be improved by applying sugarcane ripeners (SRs). However, some SRs are made from herbicides that could affect the subsequent ratoons. This study aimed to determine the effects of SRs on ratoon growth in sugarcane. The study was conducted in several plantations in North Sumatera. SRs were applied in December 2022, and the ratoons were observed in May 2023. The study used a split-split plot design with 3 treatment factors: variety (PS 881 and BZ 134), SRs application method (by drone and manual), SRs active ingredients (glyphosate, glyphosate plus Boron, and no spraying/control). The parameters observed were the number of shoots per row, the increase in gap, and the glyphosate residue in the subsequent ratoons. The results indicated a significant interaction between the application method, SRs' active ingredients and the varieties and effects of SRs on the number of shoots per row. For PS 881, the drone and glyphosate application method showed the lowest number of shoots per row. The increase in the gap and fewer shoots per row was more common with drone spraying than manual spraying. Application of SRs using drones resulted in the highest residue in PS 881 compared to the other treatments.

Keywords: Sugarcane, maturity, residue, ratoon, glyphosate

Introduction

The use of sugarcane ripeners (SRs) in Indonesia has been established for a while but has only been done in specific locations, especially in sugar factories (SFs) in Lampung. Ownership of large areas makes sugarcane ripener (SRs) spraying easier to carry out and control. In East Java, the use of SRs has increased since the 2000s in line with the abundant supply of sugarcane.[1] SRs are usually needed at the beginning of the milling season, particularly in sugarcane fields with a poor composition of varieties that are dominated by mid to late-ripening sugarcane varieties. At the beginning of the milling season, a relatively large quantity of mature sugarcane is required, while most of the existing sugarcane is still immature. Sugarcane ripening is a critical parameter that can be assessed based on the sucrose content in the internodes, and various environmental factors, such as air temperature, moisture content, low nutrient content, and high sunlight intensity, influence this.[2] In addition, the effectiveness of SRs varies, [3,4] depending on the dose or quantity of chemicals applied, the variety of sugarcane, the age of sugarcane at application, and the growing environment conditions before and after the application.[5]
In Indonesia, the SRs that are widely used are the herbicide. Four SR types of SRs can be applied to sugarcane plants: defoliant, desiccant, growth regulator, and enzyme inhibitor (herbicide).[6]

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Sugarcane ripening with SRs application will biochemically inhibit the synthesis of enzyme 5-enolpyruvylshikimate-3-phosphate (EPSP) and the synthesis of three amino acids there are phenylalanine, tyrosine, and tryptophan from the shikimate pathway. This process results in the inhibition of vegetative growth, leading to the maturity phase.[7, 8]
However, the SRs from the herbicide group can cause the shoots or growing points of sugarcane to die, and even if the user does follow the recommended application procedures, these SRs often poison the ratoons and inhibit their growth. One of them is glyphosate, which potentially causes phytotoxicity to shoots, which can negatively affect the ratoon's growth, stalk population, and crop yield.[9] As is known, ratoons develop from the primary shoots of the previous crops.[10] Glyphosate applied at moderate to high doses kills apical buds and reduces young tillers. [11, 12, 13] In addition, glyphosate is a systemic herbicide that disrupts plants' physiological processes and can also be absorbed into all plant tissues. In addition, SRs spraying has been done manually using long stick sprayers and airplanes. Even with an airplane or helicopter, spraying pesticides or ripener onto the canopy is challenging and the use of UAV in SRs spraying has not been studied in Indonesia. Both can only intervene the sugarcane at late-stage condition, so the farmer cannot intervene cost-effectively. [14] In addition, previous research on the use of SRs in various countries has been conducted, mainly on increasing maturity and sugar yield. However, the amount of active ingredient residue remaining in the subsequent ratoon's crop is unknown. Therefore, this current study aimed to assess the impact of SRs use on the development of sugar ratoons, the level of residues left behind, the growth of the subsequent ratoons, and the use of SRs in subsequent crops of different varieties and application methods.

Materials and Methods

Materials
The study was conducted on sugarcane plantations located in DP 3, Helvetia Plantation, PT Perkebunan Nusantara II, North Sumatera

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(3°39'49.0 "N and 98°36'53.7 "E). The experimental research was conducted from February 2022-May 2023 and the spraying of SRs was conducted in December 2022. Harvesting of sugarcane was carried out in January-February 2023 and observation of ratoon crops was carried out in March-May 2023.
The study utilized 2-month-old sugarcane ratoon crops where the original plants had been treated with SRs at the age of 10 months. The sugarcane plants used were PS 881 and BZ 134 varieties. The SRs used were herbicides with Glyphosate and Glyphosate plus Boron as the active ingredients (a.i). The SRs were sprayed manually using a long stick sprayer and with an unmanned aerial vehicle (UAV/ drone). The other tools were buckets and tools for agronomic observation.

Experimental Design
The observation was conducted on ratoon crops whose original plants had been sprayed with SRs. The experiment at the original plants was arranged in a split-split plot design with the main plot being the varieties (2 varieties), subplots being the SRs application methods (2 treatments), and sub-sub plots being the a.i. of SRs (3 treatments). The experiment was done in triplicate. The experiment was conducted on 2 varieties of sugarcane, early middle maturity (PS 881) and late middle maturity (BZ 134) varieties at 10 months old. The application methods were by a manual sprayer and by UAVs. The SRs contained Glyphosate and Glyphosate plus Boron as the active ingredients (a.i) and a control (no treatment). Each treatment plot consisted of 15 rows of 10 meters in length and 1.35 m in spacing.
The experimental parameters were the residual effect on the shoots of the ratoon crops by observing the shoot growth at the age of 2 months, the increase in the gap, and glyphosate residues on the ratoon plants. The number of shoots was observed by counting the number of shoots that grew at 10 meters per row. The gap increase was calculated from the difference between the initial gap before spraying and the gap after spraying. Glyphosate residues were measured using the LC-MSMS method. Analysis of glyphosate residue was carried out at the Indonesian Oil Palm Research Institute, Bogor Unit. Glyphosate residue samples used Kuijper +1 sugarcane ratoon leaves at the age of 2 months.

Statistical Analysis
Differences between treatments were statistically tested using the Least Significant Difference (LSD) test at a 0.05 significance level using Statistix 8.0 (2008).

Results and Discussion

The results of each treatment and the interaction among the treatments on the observation variables are presented in Table 1. The statistical analysis (ANOVA) of the results showed significant differences in the effects of the 3 factors tested (varieties, application methods, and a.i. of SRs) on the number of shoots per row and the increase in gap. The interaction between the application method and a.i. of SRs significantly affected the increase in the gap. In contrast, the interaction between varieties and application method significantly affected the level of glyphosate residues.
Regarding germination response, there was an opposite interaction between the application method and a.i. of SRs on the number of shoots, as shown in Figure 1. Compared to other methods, using drones resulted in more shoots in the control group than the other application methods and a.i. of SRs. In contrast, the manual method showed the lowest number of shoots in the control group.
There was a significant difference in the interaction of the three treatments (PS 881, drone, glyphosate) on the number of shoots per row compared to the other combination of treatments (PS 881, drone, glyphosate plus Boron; PS 881, drone, control; PS 881, manually, glyphosate; and BZ 134, drones, glyphosate (Table 2). Applying glyphosate or glyphosate plus Boron on PS 881 resulted in more shoots than the control, while BZ 134 showed lower results than the control. Application with drones resulted in a higher number of shoots compared to manual. The lowest number of shoots was observed in the interaction of PS 881, drone, and glyphosate with the number of shoots, i.e., 38.3 shoots per row. The results of the decrease in the number of shoots have not shown consistency in the use of SRs, both with drone and manual spraying on each variety. Meanwhile, the use of glyphosate in a field can decrease the number of tillers in the sugarcane crop, leading to reduced crop productivity in the subsequent harvest, and this ultimately causes the sugarcane field to become economically unproductive.[12] However, glyphosate at low doses (i.e. 0.005 L ha^{-1}) can enhance sugarcane maturity without affecting germination and productivity. [15] Thus, it can be said that glyphosate is feasible to use as an SRs only if it is used in the proper dosage.

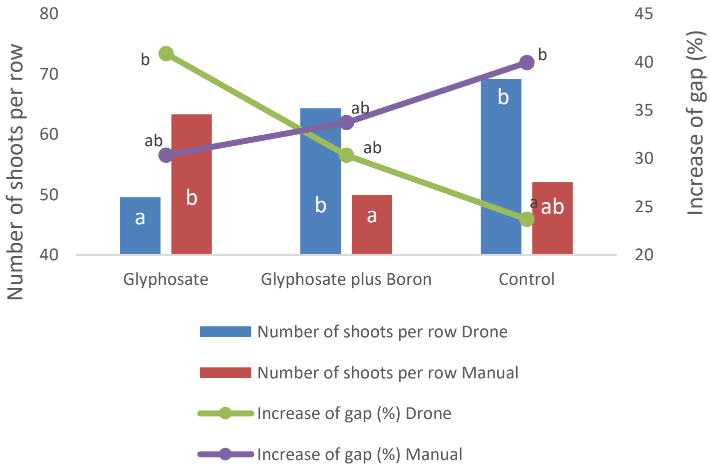

Figure 1: Relationship between application methods and active ingredients of SRs on number of shoots per row and gap increase

Table 1: Results of statistical analysis of all the parameters tested

No	F-Ratio of	Number of Shoots	Increase in gap	Glyphosate residue
1	V (Variety)	0.11	0.65	0.03*
2	A (Application Methods)	0.35	0.31	0.005**
3	R (Sugarcane Ripener)	0.75	0.51	0.3
4	V*A	0.57	0.68	0.005**
5	V*R	0.21	0.14	0.3
6	A*R	0.04*	0.006**	0.3
7	V*A*R	0.01**	0.02*	0.3

Note: **: very significant difference, *: significant difference, ns: no difference

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Table 2: Interaction among varieties, application methods, and active ingredients of SRs on the number of shoots per row and gap increase

Variety	**Application Method**	**Active Ingredients of Sugarcane Ripener**	**Number of Shoots per Row**	**Increase in Gap (%)**
PS 881	Drones	Glyphosate	38.3 a	52.22 d
PS 881	Drones	Glyphosate plus Boron	77.3 cd	25.07 ab
PS 881	Drones	Control	87.6 d	18.84 a
PS 881	Manual	Glyphosate	72.6 bcd	29.63 abc
PS 881	Manual	Glyphosate plus Boron	47.4 ab	37.21 bcd
PS 881	Manual	Control	53.3 abc	41.86 cd
BZ 134	Drones	Glyphosate	60.7 bcd	29.46 abc
BZ 134	Drones	Glyphosate plus Boron	51.3 ab	35.52 bc
BZ 134	Drones	Control	50.6 ab	28.52 abc
BZ 134	Manual	Glyphosate	53.9 abc	30.98 abc
BZ 134	Manual	Glyphosate plus Boron	52.5 ab	30.16 abc
BZ 134	Manual	Control	50.6 ab	37.94 bcd
LSD 5%			0.01	0.02
CV (%)			12.57	13.29

On the other hand, tiller mortality begins after reaching the maximum number of tillers and varies according to variety, tiller class, planting time, and cultural circumstances. Most tillers produced after 2-3 months of sowing die and do not contribute to the millable harvest. Tiller production beyond 90 DAP results in a wasteful expenditure of photosynthetic energy, as indicated by the tiller mortality of 35 for tillers formed up to 45 days, whereas the tiller mortality was 17%, 18%, and 71% for tillers formed up to 60 days, 90 days, and 120 DAP, respectively.[16] Poor sprouting, uneven and persistent tillering throughout the crop results in 60% tiller death and hence less millable canes at harvest.[17]

Furthermore, there was a significant difference in the results of the increase in ratoons' gap with the application method and active ingredients of SRs (Figure 1), as well as the interaction between varieties, application method, and active ingredient of SRs (Table 2). Figure 1 shows a significantly different interaction between the use of drones and glyphosate compared to the interaction between manual application and gap increase in the control group. The gap increase in the control still occurred even though it was untreated. This observation may be due to the high number of ratoons with subsequent reduction in the number of shoots. The number of ratoons in the world averages 2-3 times because it is related to the percentage of ratoon growth and the decrease in production of about 5-21%.[16, 18] Tiller mortality in the first ratoon crop (30.0%) was nearly identical to that of the plant crop (29.6%), whereas tiller mortality in the second ratoon crop was 28.50%. Furthermore, tiller mortality was determined by the timing of each tiller emergence and tiller growth type. However, early-formed tillers have a better probability of surviving than later shoots. [19]

In terms of increase in gap, the interaction of PS 881 using drones and glyphosate showed no significant difference from the interaction of PS 881 with glyphosate plus Boron applied manually, the control group, as well as the interaction between BZ 134 applied manually in the control. The gap increase was relatively high (> 20%) except for the PS 881 treatment with drone application and the control. The increase in gap, in the absence of spraying, may be due to the ratooning ability. Reduction in ratoon germination often reaches 50% and even 80%, primarily due to external factors that cannot be controlled as the number of ratooning increases.[21] Ratoon gaps occur as a result of inadequate sprouting, mechanical stubble damage, pests, or illnesses. Experience in numerous countries has indicated that about 25-30% of the space needs to be filled with gaps. [19]

On the other hand, the effect of different types of active ingredients of SRs on the number of shoots and the increase in sugarcane gap in this study is also corroborated by previous literature, showing that glyphosate application can significantly decrease the germination rate of sugarcane plants.[22, 23] Not only sugarcane, glyphosate can also reduce the percentage of germination in other types of plants. Glyphosate, whether in the form of roundup gold (GBH) or pure glyphosate in the soil, reduces the germination of several plant species, including fava beans (*Vicia faba* L.), oats (*Avena sativa* L.), turnip rape (*Brassica rapa* subsp. *oleifera* (DC.) Metzg.), and potatoes (*Solanum tuberosum* L.).[20]

The results showed that the interaction between varieties and application methods significantly affected the residual glyphosate of the ratoons. The treatment of PS 881 by drone application resulted in a higher glyphosate residue content and significantly differed from the other treatments (Figure 2). There was a significant difference in the treatment of varieties and application methods in each treatment, but there was no significant difference in the a.i. of SRs (Figure 3). Glyphosate residues in the PS 881 variety were higher and significantly different from the BZ 134, as well as the use of drones compared to the manual method. Regarding a.i. of SRs, there was no significant difference in the glyphosate residue, even in the control.

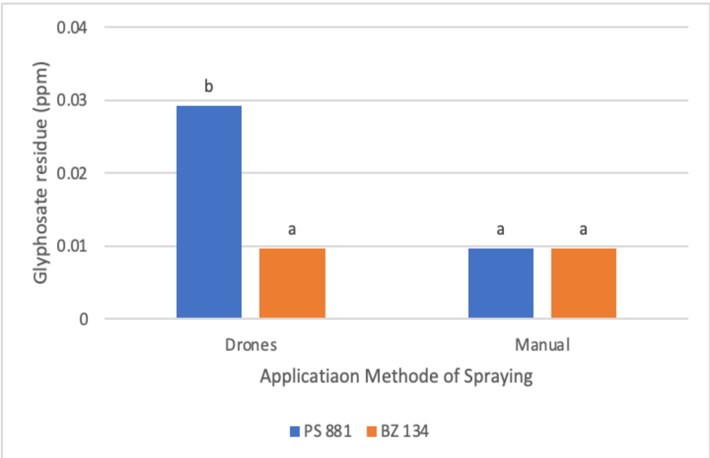

Figure 2: Relationship between variety and application methods on glyphosate residue

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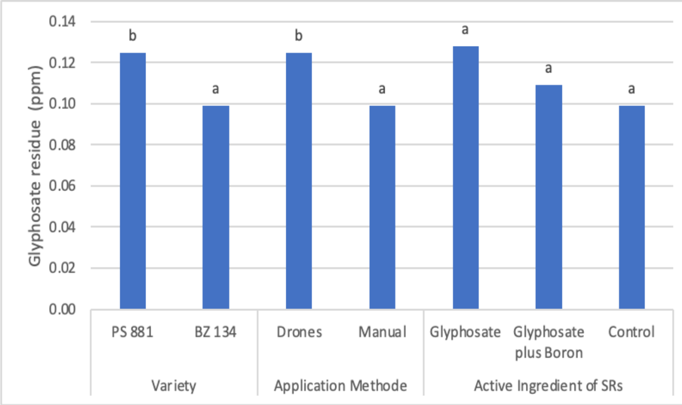

Figure 3: Glyphosate residue on each treatment factor

It is possible that the glyphosate residues in the control were obtained from the effect of chemical weed control from the cultivation, in doses ranging from 64.8–777.6 g a.e. ha^{-1} (grams of acid equivalent per hectare).[15] However, the measured herbicide residue was very low.[24-27] These results confirm that glyphosate sprayed on well-grown sugarcane at the recommended time and rate has minimal impact.[28] Nevertheless, some research findings indicate that glyphosate residues may inhibit growth, reducing shoot number, stalk height, and sugar quality. [9, 12, 15] This inhibition of germination and growth is related to suppressing nutrient absorption. Glyphosate residues can reduce the uptake and translocation of micronutrients, such as Mn and Fe, in non-target plants.[29] In addition, glyphosate residues can stimulate the formation of glyphosate metal complexes, which are insoluble micronutrients, in plant tissues or rhizospheres. These metal complexes can hinder nutrient uptake by roots and translocation by plants. To date, numerous studies have linked the ability of glyphosate to inhibit the uptake of micronutrients, such as Mn, Fe, Zn, and B, in plants exposed to glyphosate, either through spray or root uptake. [30, 31]

Conclusion

The study results showed that using glyphosate as SRs does not significantly reduce the number of shoots and increases the gap in the next ratoon. The effect of residue left on the ratoon was at a low threshold. Furthermore, using drones resulted in a higher increase in the residue of PS 881 compared to BZ 134. There were still glyphosate residues in unsprayed crops, possibly due to the use of glyphosate herbicide during chemical weed control on cultivation.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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