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Enhancement of Sugarcane Maturity using Glyphosate and Bispyribac Sodium as Chemical Ripeners in Wet Climate

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Abstract. Sugarcane is often harvested at non-optimal maturity. Chemical ripeners (CRs) could be a solution, although they risk killing subsequent ratoon plants (SRPs). This research aimed to unravel glyphosate (Gly) and bispyribac sodium (BS) impacts as CRs on sugarcane maturity and SRPs' growth. The research was conducted in Kebon Agung Sugar Mill, Malang, East Java, Indonesia, from May to July 2022, using the ten-month-old Bululawang variety and was sprayed with a drone. A randomized block design was used with four treatments, i.e., Gly 1,000 mL ha^{-1}, BS 200 mL ha^{-1}, BS 100 mL ha^{-1}, and control. Results showed that BS 200 mL ha^{-1} led to a greater rise in Cane Content Sugar (CCS) and Sugar Cristal Yield (SCY) than BS 100 mL ha^{-1} and the control but was still lower than Gly 1 l ha^{-1}. The best harvest time for optimal maturity was six to eight weeks after applying BS 200 mL ha^{-1}. The highest gap was in Gly, i.e., 45% than control and can potentially lower SCY more than other CRs, while the gaps in the 100 and 200 mL ha^{-1} BS were 7.82% and 11.97%, respectively. The results suggest that low doses of Gly and BS can boost maturity and also avert SRPs' death.

1 Introduction

One of the problems of the Indonesian sugar industry is the poor quality of milled sugarcane. This is due, in part, to sugarcane not being harvested at optimal maturity degree due to the prominence of using mid and late-ripening varieties, excess nitrogen, and wet climate conditions for most of the year, especially outside Java Island. In Indonesia, sugarcane is extensively grown in temperature and humidity conditions that do not espouse the natural ripening process [1]. The presence of climate anomalies, such as La-Nina, further exacerbated this matter [2, 3]. Meanwhile, sugar mills are often forced to harvest sugarcane that is not yet ripe to comply with milling capacity [4]. Consequently, sugarcane is usually harvested when the sucrose percentage is less than ideal, primarily when it is harvested at the outset of the milling season.

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A practical way to surmount the issue is using a chemical ripener (CR). Preceding studies have proven a rise in sugarcane sucrose content along with CR application [5, 6]. CR can be applied to sugarcane that is physiologically immature or confronts delayed maturity for various reasons, such as the conditions of exaggerated nitrogen and water [7, 8].

Both sugar industries and smallholder farmers can implement CR. Sucrose increase due to CR application could cover the costs of using CR. On the industrial scale, the rationale for using CR can be supported from numerous viewpoints. First, a rise in sucrose percentage reduces the unit cost per ton of sugar produced. This is achieved by reducing the costs of transporting cane and milling for each unit of sugar produced. Second, boosting overall sugar production aids in increasing returns on investments the industry makes outside plantations. Third, CR could potentially extend the milling season. The lowest break-even point for using CR is a CCS increase of 0.25% than without CR [9]. Deliberating on the advantages shown by CR, it is paramount to assess its impact on sugarcane, especially CCS, SCY, and SP, without damaging SRPs' growth and development. The opportunity to use CR is quite high considering the changing climatic conditions in Indonesia and the high use of nitrogen fertilizers in farmers which can inhibit the process of sugarcane maturity. This research aimed to discover a CR formulation that effectively raises sugarcane ripening without interfering with SRPs.

2 Materials and method

This field experiment was performed in the Kebon Agung Sugar Mill area in Malang Regency, East Java, Indonesia, between May to July 2022. Cane Content Sugar analysis was carried out in the testing laboratory of the Indonesian Sugar Research Institute, Pasuruan, East Java, Indonesia.

2.1 Materials and tools

The materials used as CR were Gly and BS. The sugarcane variety used was 10-month-old Bululawang which was planted in July 2021 on a roughly one-hectare land area. CR was sprayed with a spraying drone equipped with a tank and nozzle. The CR solvent used was 60 liters per ha, or 10 l of water per 1,700 m^2.

2.2 Experimental design

This research was arranged in a randomized block design with six replications as a group. There were four treatments given, i.e., Gly of 1,000 mL ha^{-1}; BS of 200 mL ha^{-1}; BS of 100 mL ha^{-1}, and control (without CR spraying). Each treatment plot consisted of 20 rows. Each row was 10 meters long, and the distance from center to center of the rows was 1.20 m. A 0.5-m control road and a 0.6-m gutter were built as barriers between treatment plots. CR spraying was conducted in May 2022 when sugarcane was ten months old. The spraying routes for all the CR treatments are portrayed in Fig. 1.

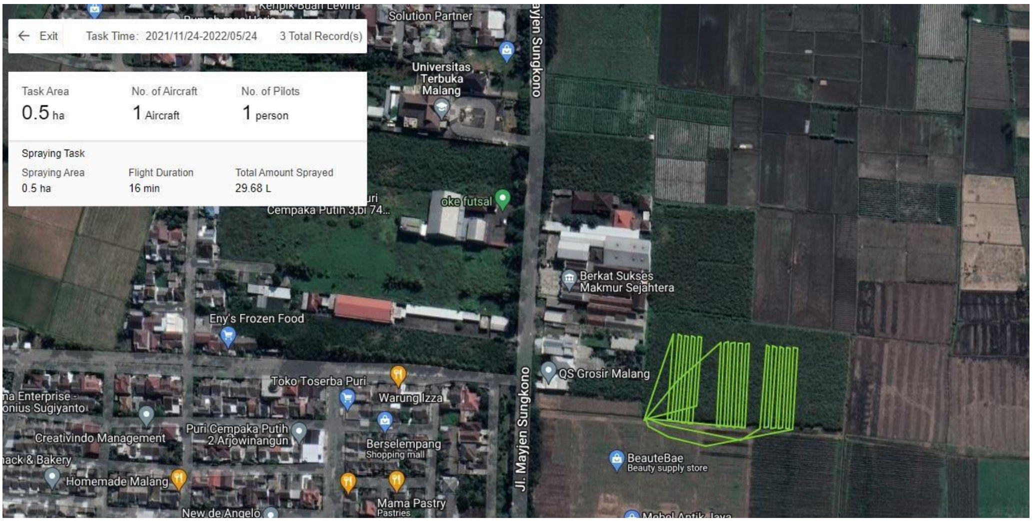

Fig. 1. Map of the spraying routes by drone of the three CR treatments (the green lines)

2.3 Sugarcane harvesting and observation

Sugarcane harvesting was executed four, six, and eight weeks after CR application. At each harvest time, samples from four rows with 10 m length were taken. Some observation parameters scrutinized at each harvest time were Cane Content Sugar (CCS), Sugar Cristal Yield (SCY), and Sugar Productivity (SP). Besides, it was also observed whether or not there was a residual effect on the shoots of SRPs by monitoring the number of clumps per meter, gap (%), and potential reduction in sugarcane productivity to control (%). Gap, representing shoot death, was determined by gauging empty spaces of 50 cm or more in each row [10]. Next, differences between treatments were statistically tested using the Least Significant Difference (LSD) Test at a significance level of 5% using Statistix 8 software.

3 Results and discussion

3.1 Sugarcane productivity, cane content sugar and sugar crystal yield

Table 1 shows that applying Gly of 1,000 mL ha^{-1} led to the highest CCS and is markedly different from the three other treatments, revealing the significance of this chemical substance to be used as CR. In the meantime, the CCS at the BS 200 mL ha^{-1}, 100 mL ha^{-1}, and control at eight weeks after CR application are not significantly different, i.e., 8.02%, 8.15%, and 8.39%, respectively.

SCY values are statistically not different among all the treatments at eight weeks after CR application, implying that adding the two types of CR at the designated doses does not affect SCY compared to the control. Nevertheless, it is enticing to notice that SCY increased over time, signifying the eight weeks after CR application as the best harvest time to obtain the highest SCY.

Table 1. Sugarcane productivity (t ha^{-1}), Cane Content Sugar (%) and sugar crystal yield (t ha^{-1}) at four, six, and eight weeks after CR application

Treatments	**Weeks after CR application**		
	4	**6**	**8**
	Sugarcane productivity (t ha^{-1})		
Glyphosate 1,000 mL ha^{-1}	96.06 a	88.32 a	112.20 a
Bispyribac sodium 200 mL ha^{-1}	93.99 a	117.08 c	148.68 b
Bispyribac sodium 100 mL ha^{-1}	114.15 ab	95.40 ab	137.29 b
Control	124.02 b	111.96 bc	132.03 ab
	Cane Content Sugar (%)		
Glyphosate 1,000 mL ha^{-1}	10.10 b	9.94 c	10.89 b
Bispyribac sodium 200 mL ha^{-1}	8.58 ab	9.08 bc	8.02 a
Bispyribac sodium 100 mL ha^{-1}	8.20 a	7.58 a	8.15 a
Control	8.10 a	8.18 ab	8.39 a
	Sugar crystal yield (t ha^{-1})		
Glyphosate 1,000 mL ha^{-1}	9.69 a	8.67 ab	12.21 a
Bispyribac sodium 200 mL ha^{-1}	8.03 a	10.55 c	11.89 a
Bispyribac sodium 100 mL ha^{-1}	9.32 a	7.21 a	11.11 a
Control	10.19 a	9.08 bc	11.07 a

Note: Numbers followed by the same letter are not significantly different (and vice versa) according to the Least Significant Difference Test at the 5% level

Meanwhile, the SP of Gly of 1,000 ml ha^{-1} are the lowest and significantly different from the other three treatments at six and eight weeks after CR application. This result aligns with some studies showing that Gly tends to reduce sugarcane productivity. Gly is the most effective chemical for increasing sucrose content and sugar recovery during early season harvest in sugarcane. Although Gly causes a moderate decrease in sugarcane tonnage and leaf desiccation, it is still considered the most suitable and economical chemical to increase sugar recovery in the climatic conditions of Khuzestan [11]. In Gly, the active compound is rapidly translocated to the shoot apical meristem, which can suppress new tissue formation [12] by inhibiting the plant enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) in the aromatic amino acid (AAA) biosynthetic pathway, also known as the shikimate pathway [13].

3.2 Number of clumps per meter, gap, and the potential decline in SRPs

Observation of SRPs was carried out by measuring the number of clumps per meter, gap (%), and potential reduction in sugarcane productivity to control (%). Among all the treatments, the lowest clump number per meter is in sugarcane plots treated with Gly of 1,000 mL ha^{-1}. This number is remarkably different from the other treatments. This is in line with the results of the gap measurement, demonstrating that the highest gap is in the Gly of 1,000 mL ha^{-1} treatment. The higher the gap, the higher the sugarcane shoot death and the lower the number of clumps per meter, and vice versa. The highest potential reduction of sugarcane productivity to control is in the Gly of 1,000 mL ha^{-1} treatment, i.e., up to 45%. Meanwhile, the potential decrease in sugarcane productivity to control in the treatment of BS of 200 mL ha^{-1} and 100 mL ha^{-1} are only 11.97% and 7.82%, respectively (Table 2).

Overall, the results of SRP observation denote the importance of reevaluating the use of Gly as CR. Although it has the most promising potential to increase CCS, its impact on the death of SRPs needs to be carefully considered. In line with that, applying Gly for three consecutive years enhanced sugar yield by 7% yet lowered total cane yield by 4% [13]. However, Gly is promising and effective CR to enhance CCS without damaging SRPs if used in low doses [5]. They suggested that the Gly application of 5 mL ha^{-1} improved Brix% juice, pol% cane, purity% juice, moisture% cane, reducing sugars, total reducing sugars, total recoverable sugar, and pol productivity and did not affect ratoon sprouting in the SRPs. In the context of this research, using Gly of less than 1,000 mL ha^{-1} needs to be studied in the ensuing identical research to observe whether it leads to the reduction of SRP death and to look at the impact on the CCS.

Table 2. The number of clumps per meter, gap, and the potential decline in sugarcane productivity to control of one-month subsequent ratoon

Treatments	Number of clumps per meter	Gap (%)	Potential reduction in sugarcane productivity to control (%)
Glyphosate 1,000 mL ha^{-1}	2.16 a	45.11 b	45.02
Bispyribac sodium 200 mL ha^{-1}	2.37 b	39.87 a	11.97
Bispyribac sodium 100 mL ha^{-1}	2.62 c	37.93 a	7.82
Control	2.91 d	36.86 a	-

Note: Numbers followed by the same letter are not significantly different (and vice versa) according to the Least Significant Difference Test at the 5% level

4 Conclusion

Bispyribac sodium has the potential to increase sugarcane maturity, resulting in an increase in yield compared to the control. Bispyribac sodium of 200 mL ha^{-1} led to a better increase in commercial cane sugar and sugar crystal yield than byspiribac sodium of 100 mL ha^{-1} and control but was still lower than glyphosate. The best harvest time for optimal maturity levels was six to eight weeks after CR application using Bispyribac sodium of 200 mL ha^{-1}. The highest gap occurred in the glyphosate treatment, i.e., 45% compared to the control and could potentially lower sugarcane productivity the highest compared to other CR treatments. Shoot death percentage of subsequent ratoon plants (gap) with the Bispyribac sodium of 100 mL ha^{-1} and 200 mL ha^{-1} was 7.82% and 11.97%, respectively, compared to the control.

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