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Exogenous spraying of plant's resistance inducers improves yield and sugarcane quality

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Abstract

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Sugarcane crop is important to sugar-energy industry. Thus, the aim of this study was to evaluate yield and technological quality of Sugarcane juice obtained from the SP81-3250 variety following exogenous spraying of resistance inducers. The experiment consisted of a randomized block design with four replicates per treatment: salicylic acid (0, 5, 10, 20, and 40 µM) and acibenzolar-S-methyl (0, 0.2, 0.4, 0.8 and 1.6 g 100 L^{-1}). The resistance inducers were sprayed using CO_2-pressurized sprayer. Sugarcane tillage was harvested thirty-days after the spraying of resistance inducers and stalks were milled for juice samples extraction, in which were evaluated the following parameters: °Brix, Pol, purity, reducing sugars (RS), total reducing sugars (TRS), theoretical sugar recoverable (TSR), fibres and yields of sugar and stalks. Obtained data was submitted to following statistical tests ($P < 0.05$): Shapiro-Wilk's normality, Fisher's variance, regression, and Pearson's linear correlation. Results showed that quadratic trends rejected null hypothesis for almost all parameters. Salicylic acid levels till 10 µM increased °Brix, Pol, purity, TRS, TSR contents and sugar and stalks yield. However, 20 and 40 µM showed negative effects on juice technological quality and agronomic performance. Therefore, the elicitors improved photosynthetic characteristics and sugarcane physiological maturation. It was concluded that salicylic acid and acibenzolar-S-methyl levels till 10 µM and 0.8 g 100 L^{-1}, respectively, are recommendable to management of SP81-3250 variety.

Keywords: acibenzolar-S-methyl; phytohormones; plant resistance; inducers; salicylic acid; *Saccharum* spp.

Introduction

The sugar-energy industry is essential to world's sustainability, once it offers many environmental and socioeconomic advantages, including: job opportunities, mitigation of global warming negative effects, by the biological fixation of CO_2, food production, and alternative biofuels to the petroleum, natural gas, and mineral coal (Leal et al., 2013; Matsuoka et al., 2014).

In Brazil, for instance, sugar (crystal, demerara, VHP, and brown) and bioethanol (first and second generation) are, often, obtained from sugarcane (*Saccharum spp.*) industrialization.

That way, this agricultural crop is indispensable to Energetic Matrix diversification and Brazilian economic evolution (Boaretto & Mazzafera, 2013; Oliveira et al., 2016).

Original from Asia's southeast, sugarcane is a grass specie belonging to Poaceae botanical family characterized by the ability of adaptation to tropical, subtropical and temperate climates, tolerance to environmental adverse conditions: such as water stress, critical photoperiod, and pests attack; furthermore, this C_4 plant is completely fit to agricultural mechanization (Waclawovsky et al., 2010; Boaretto et al., 2014; Viana et al., 2017).

Agronomic performance and industrial quality of sugarcane are severely affected by many biotic and abiotic factors, such as genotype, phytopathogens, heat stress, salinity and low soil fertility, atmospheric pollution, heavy metals, etc. Therefore, the use of induced-resistance technique is a solution to palliate negative effects from these agents and enhance yield of this crop (Nazar et al., 2011; Yazdanpanah et al., 2011; Palma et al., 2013).

Salicylic acid (SA) and acibenzolar-S-methyl (ASM) are examples of resistance inducers successful used on agriculture. The first is an endogenous hormone synthesized, basically, by two enzymatic pathways: a) phenylpropanoid: benzoic acid is turned to 2-hydroxy benzoic acid (SA) by the benzoic-2-hydroxylase enzyme; b) on chloroplasts: isorismate-synthase enzyme convert chorismate to isochorismate, which is finally turned to SA; as the last is an AS (Jin et al., 2008; Vazirimehr et al., 2014).

These compounds play an important role on plant defence system, once they act like signal substances for synthesis of PR-proteins (chitinases and β-1,3-glucanases), phytoalexins, antimicrobian secondary metabolites (phenols, ascorbic acid, and alkaloids), antioxidant enzymes, among others chemical and physical mechanisms against negative effects from biotic and abiotic agents. Moreover, these elicitors are able to improve photosynthetic activity and ethylene formation, factors that influence yield and sugarcane physiological ripening (Hayat et al., 2010; Khan et al., 2010; Janda et al., 2012; Khan et al., 2013; Liu et al., 2014). Therefore, this study aimed to evaluate agronomic performance and SP81-3250 variety juice quality after exogenous spraying of SA and ASM.

Material and Methods

Site

The research was carried out at Santo Antonio Ubasa farm, based on São Paulo, Brazil, during the 2008/2009 agricultural season. According to Köppen-Geiger the regional climate is characterized by dry winter and rainy summer.

Experimental design

The experiment consisted of a randomized block design with four replicates per treatment: salicylic acid (0, 5, 10, 20 and 40 μM) and acibenzolar-S-methyl (0, 0.2, 0.4, 0.8 and 1.6 g 100 L^{-1}).

Soil preparation, sugarcane planting and pest management

The acidity and soil fertility were adjusted by dolomitic limestone (2.0 t/ha^{-1}) and NPK-fertilizer (0.5 t/ha^{-1}) application, respectively. Two months after, was carried out planting of the SP81-3250 variety, distributing fifteen sugarcane buds at five plantation furrows with 5 m length, spaced at 1.4 m. Pests management was carried out by imidacloprid (1.4 L/ha^{-1}) spraying.

Resistance inducers spraying

SA and ASM were sprayed two-month before sugarcane flowering period, using CO_2-pressurized sprayer with six flat spray nozzles (11002); previously, pressure and spray solution volume were adjusted to 40 lb/pol^2 and 300 L/ha^{-1}, respectively (Viana et al., 2017). Temperature and relative air humidity averages at spraying moment were to 25.5 ± 2.5°C and 70 ± 10%, respectively; there was no subsequent rainfall.

Harvest and technical assessment

The harvest of sugarcane tillage was carried out thirty days after the resistance inducers spraying. In laboratory, stalks were milled for juice samples, subsequently, it was set the following parameters: °Brix, Pol, purity, reducing sugars (RS), total reducing sugars (TRS), theoretical sugar recoverable (TSR), fibres and yields of sugar and stalks (Oliveira et al., 2016).

Statistical analyses

Data set was subjected to following tests ($P < 0.05$): Shapiro-Wilk's normality, Fisher's variance, regression, and Pearson's linear correlation; optimal levels for some parameters were calculated by differential methods, using *Software R* statistical packages.

Results and Discussion

Analysis of variance (*ANOVA*)

Obtained data distributed themselves, which provides security to *ANOVA* results interpretation (Table 1).

In summary, results revealed that quadratic trends rejected null hypothesis only for purity and fibres, in relation to the SA, and Pol, purity, RS, TSR, and yields of sugar and stalks, in ASM case, suggesting that other unknown factors

Table 1. Shapiro-Wilk's normality test for salicylic acid (SA) and acibenzolar-S-methyl (ASM) effects on agronomic performance and SP81-3250 variety juice technological quality

SA	°Brix	Pol	Purity	SR	TSR	Fibers	TRS	Sugar	Stalks
P-value	$1,80^{ns}$	4.16^{ns}	13.73^{*}	2.32^{ns}	4.56^{ns}	11.68^{*}	9.16^{ns}	1.67^{ns}	0.17^{ns}
ASM	°Brix	Pol	Purity	SR	TSR	Fibers	TRS	Sugar	Stalks
P-value	1.41^{ns}	13.31^{*}	36.01^{*}	9.43^{*}	4.90^{*}	1.87^{ns}	14.28^{*}	7.64^{*}	6.24^{*}

Significance codes: *($P < 0.05$) and ^{ns}($P \geq 0.05$)

significantly affected, the agronomic performance and technological quality of SP81-3250 variety's juice.

Salicylic acid (SA)-induced effects

SA-induced effects on agronomic performance and SP81-3250 variety juice technological quality as Figure 1 shows.

SA-induced °Brix (% juice)

Regression equation adjusted to technological parameter showed that only 28.77% of the fixation of total soluble solids (TSS) on physical-chemical composition of SP81-3250 variety's juice was induced, exceptionally, by the SA exogenous treatment. It was checked that SA doses from 20 μM had negative effects on feedstock TSS content, while the less concentrated dosages (5 and 10 μM) provided benefits to the °Brix, regarding to control.

SA-induced Pol (% juice)

Despite to statistical insignificance, the trend adjusted to the Pol revealed that 61.27% of the production and sucrose retention on SP81-3250 variety juice was caused by bio-

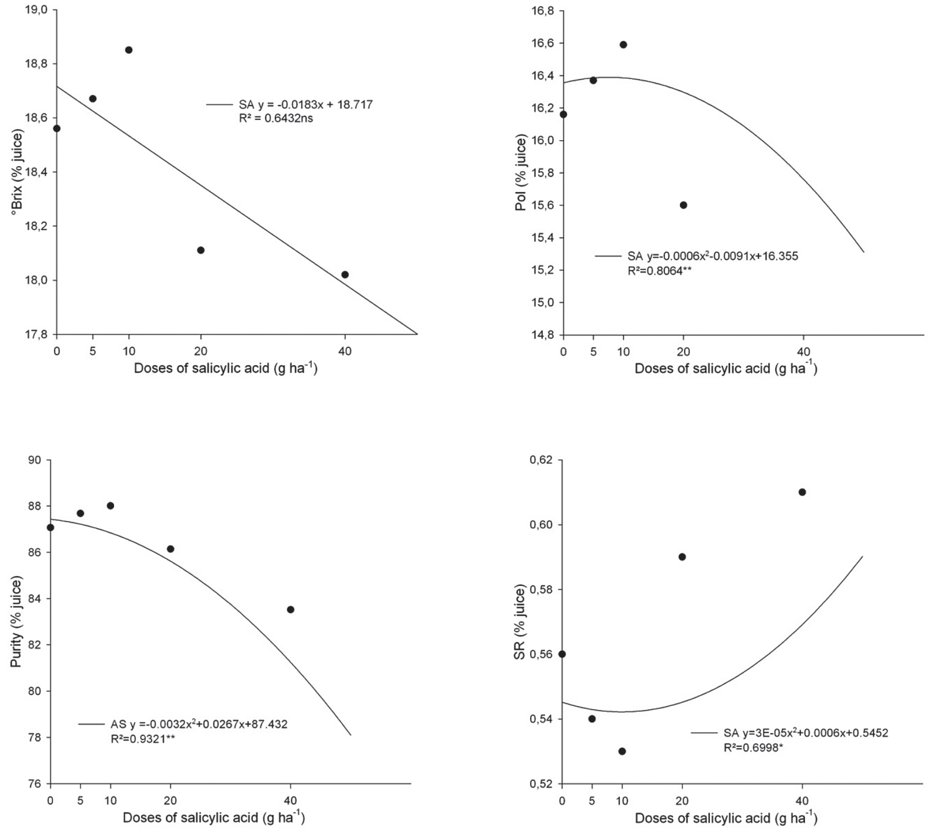

Fig. 1. Salicylic acid (SA) effects on agronomic performance and SP81-3250 variety juice technological quality; significance codes: *($P < 0.05$) and ^{ns}($P \geq 0.05$)

Source: author

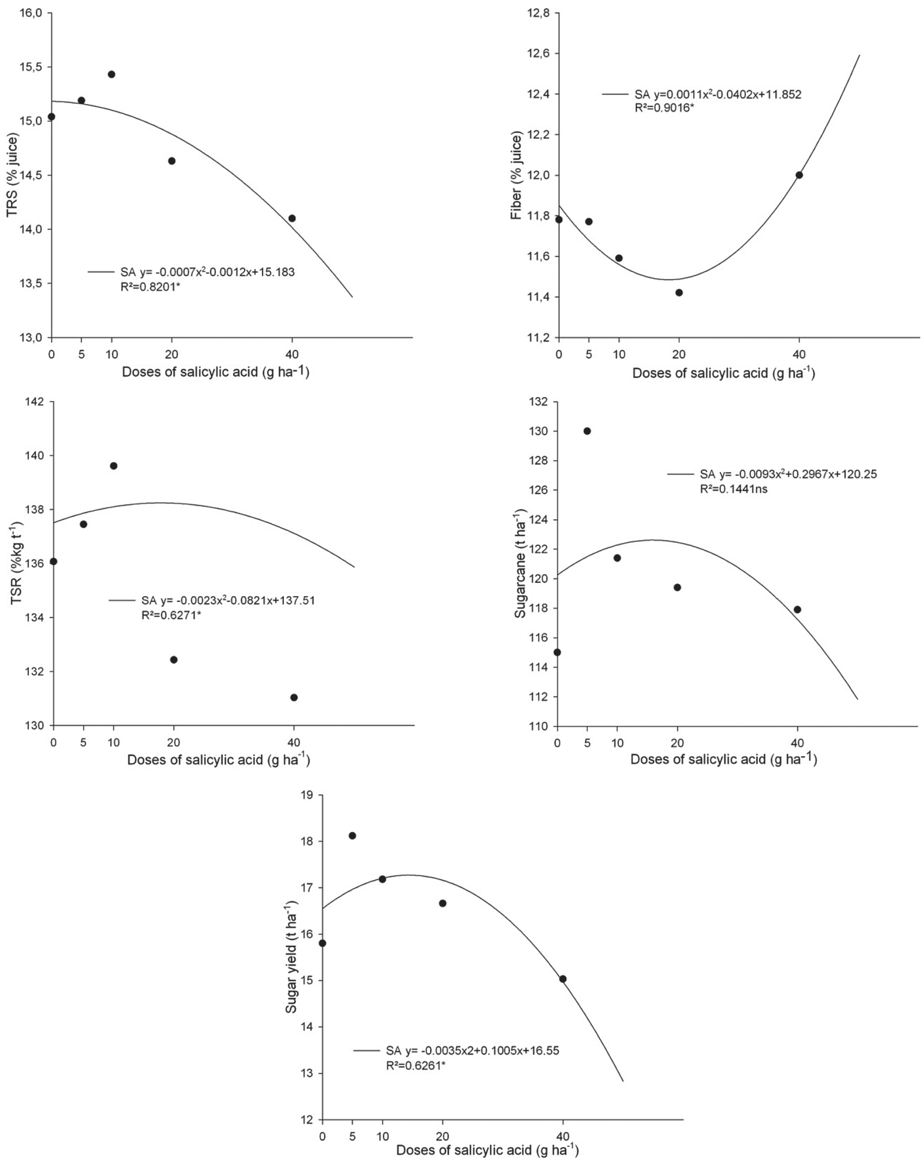

Fig. 1. Continued

chemical and physiological modifications directly induced by the SA systemic activity. The SA´s less concentrated levels (5 and 10 µM) enhanced Pol content, unlikely it occurs in 20 and 40 µM, in which sucrose decrease was detected, regarding to control. Furthermore, the increase in the SA concentration (from 10 for 40 µM) resulted in a reduction of nearly on point five percent point on Pol. Therefore, there was antagonic relation between juice sucrose content and SA concentration.

SA-induced purity (% juice)

The SA exogenous spraying lead to 86.43%-variation on purity of SP81-3250 variety's juice. The treatments (control and 5 µM) displayed similar performances, with slight numeric superiority in favour of the SA level. As checked, previously, in relation to °Brix and Pol, more concentrated SA levels (20 and 40 µM) decreased juice's purity nearly two and four percentage points, respectively, contrasted to 10 µM, appointing unbalance in the sucrose/TSS ratio. Hypothetically, it would be possible obtain the highest purity, if it were sprayed about 4.20 μM SA, considering the equation ($0 = -0.0064x + 0.0267$), which is derived from trend adjusted to this technological parameter.

SA- induced RS (% juice)

According to the equation adjusted to this parameter, SA influence on synthesis, also, reduction of sugars fixation on SP81-3250 variety's juice was not expressive, concerning its physical-chemical composition, since it corresponded to 39.97%. In the general comparative between treatments, less concentrated SA levels (5 and 10 μM) caused reductions at glucose and fructose contents, while 20 and 40 μM resulted in RS increase, regarding to control. Thus, it was verified synergistic relation between SA concentration and RS content, supporting so hypothesis of this study.

SA-induced TRS (% juice)

Plants submitted to 5 and 10 μM levels produced juices with average TRS higher than plants treated with 20 and 40 μM. The increase in the AS concentration (from 10 for 40 μM) provided decrease of nearly one and a half percentage point at TRS. Therefore, it was checked out that more concentrated SA levels caused juice´s quality reduction, once it showed negative effects on TRS content, influenced at 64.01% by the resistance inducer systemic activity.

SA-induced fibres (% cane)

Regression model adjusted to this parameter showed that SA levels till 20 μM decreased, slightly, fibres percentage, unlike to dosages higher than this limit, which they stimulated the biomass lignification, resulting in more fibrous stalks. Theoretically, it would be possible reach less fibres content, if it were sprayed about 18.30 μM SA, considering the equation ($0 = -0.0022x + 0.0402$), which is derived from trend adjusted to fibres, attributing 80.32% to biochemical and physiological modifications induced from SA exogenous spraying.

SA- induced sugar yield

The SA levels (5, 10, and 20 μM) increased sugar yield; however, there was progressive decrease from of the intermediate dose. Regarding to control, the less concentrated SA level (5 μM) provided increase of nearly 2.30 t/ha^{-1} at sugar yield, unlike to 40 μM, which presented technique efficiency lower than control. Therefore, it was checked that more concentrated SA levels restricted the biological potential of SP81-3250 variety.

SA-induced stalks yield

In summary, all the used SA levels have had positive effects on stalks yield, since 5, 10, 20 and 40 μM resulted in increases of nearly 15.40, 6.40, 4.40, and 2.90 t/ha^{-1} respectively, regarding to control. So, the curve inflexion point happened at 5 μM level, appointing that from this concentration there was decrease at stalks yield. So, considering all presented results, it was verified that SA levels above 10 μM prejudiced agronomic performance and technological quality of SP81-3250 variety's juice.

Acibenzolar-S-methyl (ASM)-induced effects

Figure 2 shows ASM-induced effects on agronomic performance and technological quality of SP81-3250 variety's juice.

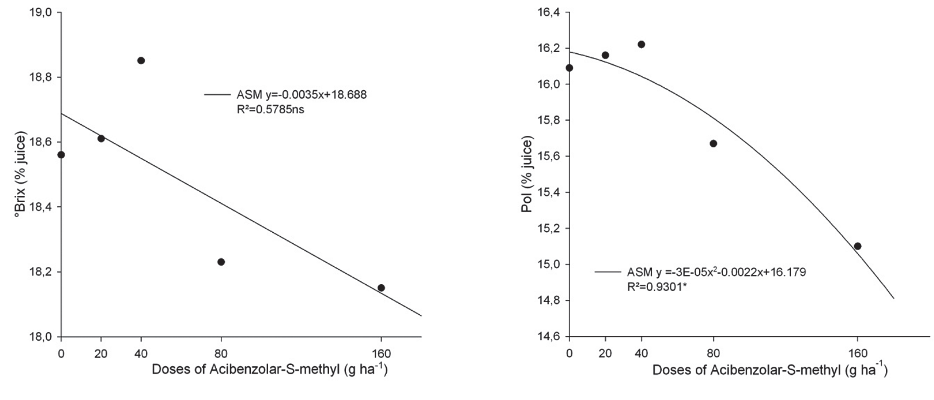

Fig. 2. Acibenzolar-S-methyl (ASM) effects on agronomic performance and technological quality of SP81-3250 variety´s juice; significance codes: *($P < 0.05$) and ^{ns}($P \geq 0.05$)

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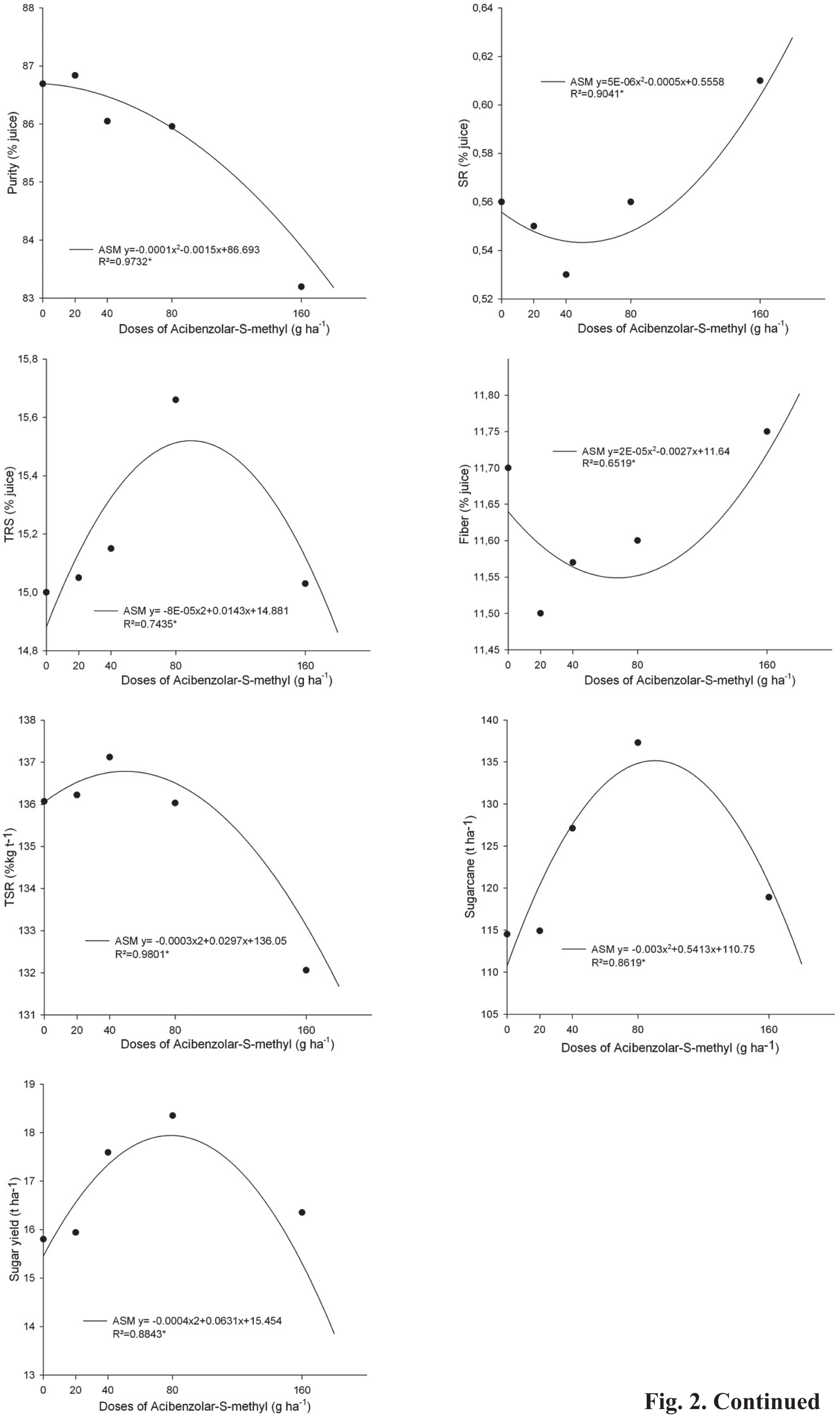

Fig. 2. Continued

ASM-induced °Brix **(% juice)**

The regression curve adjusted to this technological parameter appointed that only 16.99% of the variation happened at TSS fixation on SP81-3250 variety's juice were motivated, exclusively, by the SA exogenous treatment. Plants treated with 0.2 g 100 L^{-1} produced juices with TSS content slightly higher, as compared to those no submitted to ASM exogenous spraying. The highest °Brix average was presented by 0.4 g 100 L^{-1}, unlike to more concentrated levels (0.8 and 1.6 g 100 L^{-1}), in which antagonic effects were promoted regarding to TSS production, resulting in juice's quality depreciation. Thus, there was negative relation between ASM level and °Brix.

ASM-induced Pol (% juice)

The ASM exogenous spraying was responsible for 86.02% of the variation that occurred on sucrose accumulation on SP81-3250 variety's juice. The less concentrated ASM levels (0.2 and 0.4 g 100 L^{-1}) lead to Pol increase, improving technological quality of the juice. In another hand, the more concentrated ASM levels (0.8 and 1.6 g 100 L^{-1}) caused reduction in the Pol content, resulting in feedstock industrial quality depreciation. In addition, the increase in the ASM concentration (from 0.4 for 1.6 g 100 L^{-1}) reduced Pol content in more than one percentage point. Therefore, an inverse relation was detected between ASM concentration and juice sucrose percentage.

ASM-induced purity (% juice)

According to regression model adjusted to this parameter, SA exogenous treatment was responsible for 94.60% of the variation occurred in juice's purity. Regarding to control, just the less concentrated ASM level (0.2 g 100 L^{-1}) increased purity; from this level, progressive decrease were detected in the purity content, it was intensified at more concentrated ASM levels (0.8 and 1.6 g 100 L^{-1}), in which they reduced purity content in about four percentage point. So, every ASM levels above 0.2 g 100 L^{-1} were harmful to feedstock purity.

ASM-induced RS (% juice)

The less concentrated ASM levels (0.2 and 0.4 g 100 L^{-1}) reduced RS content, regarding to control. In another hand, 0.8 and 1.6 g 100 L^{-1} benefited glucose and fructose participations on physical-chemical composition of SP81-3250 variety´s juice. Despite to divergences, ASM levels presented similar technique performances. Hypothetically, it would be possible reach less RS content, whether it were sprayed about to 0.47 g ASM 100 L^{-1}, considering the equation (0 = 0.1054x – 0.0495), which is derived from adjusted regression to total percentage of reducing sugars, attributed at 80.83% to the ASM effects.

ASM-induced TRS (% juice)

The ASM levels (0.2, 0.4, and 1.6 g 100 L^{-1}) resulted in similar TRS averages, while 0.8 g 100 L^{-1} provided an increase of nearly one percentage point considering this technological parameter. In addition, the increase in the ASM concentration (from 0.8 for 1.6 g 100 L^{-1}) reduced TRS in more than one percentage point, depreciating technological quality of SP81-3250 variety´s juice. That way, it was checked negative relation between ASM concentration and TRS percentage.

ASM-induced fibres (% cane)

According to regression model adjusted to this parameter, 30.37% of the fibres accumulation in the biomass was directly caused by the ASM exogenous spraying. The less concentrated ASM levels (0.2, 0.4, and 1.8 g 100 L^{-1}) reduced slightly the feedstock fibres content, regarding to control. In another hand, 1.6 g 100 L^{-1} induced SP81-3250 variety to production of more fibrous stalks. Despite to divergences, ASM levels presented similar technique performances.

ASM-induced TSR

The treatments (control, 0.2, and 0.8 g 100 L^{-1}) presented similar performances, with slight numeric superiority in favour of the less concentrated ASM level. The curve inflexion point occurred at 0.4 g 100 L^{-1}, which is linked to the highest TSR average. In another hand, the more concentrated ASM level (1.6 g 100 L^{-1}) caused reduction of about to 4.0 t/ha^{-1} at TSR yield, regarding to control. Theoretically, it would be possible reach the highest TRS yield, whether it were sprayed about to 0.44 g ASM 100 L^{1}, considering the equation (0 = -6.8486x + 2.9701) derived from adjusted regression to the TSR, explained at 96.02% by the ASM effects.

ASM-induced sugar yield

Control and the less concentrated ASM level (0.2 g 100 L^{-1}) showed similar sugar yield averages, with slight numeric superiority in favour of dosage. In relation to the others ASM levels (0.4, 0.8, and 1.6 g 100 L^{-1}), these also had positive effects on sugar yield, once they promote increases of nearly 1.8, 2.6, and 0.6 t/ha^{-1}, respectively, regarding to control. Therefore, the highest sugar yield average was presented in 0.8 g 100 L^{-1} doses; from this level, occurred a decrease of about to 2.0 t/ha^{-1} in the sugar yield. Hypothetically, it would be possible reach the highest sugar yield, whether it were sprayed about to 0.88 g ASM 100 L^{-1}, considering the equation (0 = -7.1606x + 6.3113), which is derived from adjusted trend to sugar yield, which was driven at 76.86% by the effects of ASM exogenous spraying.

ASM-induced stalks yield

The ASM levels (0.2, 0.4, 0.8, and 1.6 g 100 L^{-1}) provided increases close to 0.4, 12.6, 22.8, and 4.4 t/ha^{-1} to the stalks yield, regarding to control. So, the curve inflexion point happened at 0.8 g 100 L^{-1}, appointing that from of this level there was reduction of nearly 18.4 t/ha^{-1} in the stalks yield, corroborating previous findings, which they revealed that ASM levels higher than 0.8 g 100 L^{-1} caused adverse effects on both agronomic performance and SP81-3250 variety´s juice technological quality. In conclusion, it would be possible reach top stalks yield, whether it were sprayed about to 0.89 g ASM 100 L^{-1}, considering equation $(0 = -60.856x + 54.131)$ derived from trend adjusted to stalks yield, attributed at 72.39% to the ASM exogenous treatment.

Linear correlation

Table 2 shows the linear associations established between resistance inducers, technological parameters of the juice, and yield traits.

Linear correlation for salicylic acid (SA)

Just the parameters (Pol and purity) established significant correlations with SA levels. In both situation, negative linear associations were detected, appointing that plants treated with more concentrated SA levels produced poorer juices regarding to sucrose and purity. Same way, °Brix, TRS, TSR, and sugar and stalks yields also established negative correlations with SA level, although, no significant associations were detected, differently from the others parameters (RS and fibres). About to correlations involving exclusively technological parameters of the juice, it was checked that °Brix was associated, positively, with Pol, purity, TRS and TSR, and negatively with RS, suggesting that less concentrate feedstock in glucose and fructose reached higher polarization degree, resulting in a purer juice.

Linear correlation for acibenzolar-S-methyl (ASM)

As checked, previously, in relation to the SA, only Pol and purity were associated, significantly, with ASM levels. In both cases, negative linear associations were detected, implying that plants submitted to ASM more concentrated doses produced less pure and polarized juices. In relation to the others parameters, °Brix and TSR established negative correlations with ASM levels, while RS, TRS, fibres, and yields of sugar and stalks were associated, positively; however, in all cases, significant associations were not found. Finally, it was verified positive correlation between yields of sugar and stalks and TSR, suggesting that stalks availability per grown area influenced, positively, the sucrose production.

Table 2. Linear correlation between salicylic acid (SA) and acibenzolar-S-methyl (ASM) levels, juice technological parameters, and yield traits from SP81-3250 variety

	X\y	°Brix	Pol	Purity	RS	TRS	Fibers	TSR	Sugar	Stalks
SA	°Brix	1.00*	0.97*	0.89*	-0.97*	0.96*	-0.17^{ns}	0.99*	0.65^{ns}	0.41^{ns}
	Pol		1.00*	0.97*	-0.99*	0.99*	-0.36^{ns}	0.98*	0.74^{ns}	0.43^{ns}
	Purity			1.00*	-0.94*	0.98*	-0.53^{ns}	0.91*	0.79^{ns}	0.43^{ns}
	RS				1.00*	-0.98*	0.28^{ns}	-0.99*	-0.76^{ns}	-0.51^{ns}
	TRS					1.00*	-0.42^{ns}	0.97*	0.74^{ns}	0.41^{ns}
	Fibers						1.00*	-0.24^{ns}	-0.48^{ns}	-0.07^{ns}
	TSR							1.00*	0.69^{ns}	0.43^{ns}
	Sugar								1.00*	0.86^{ns}
	Stalks									1.00*
ASM	Stalks									1.00*
	Sugar								1.00*	0.99*
	TSR							1.00*	0.28^{ns}	0.23^{ns}
	Fibers						1.00*	-0.73^{ns}	-0.24^{ns}	-0.18^{ns}
	TRS					1.00*	-0.24^{ns}	0.24^{ns}	0.88*	0.93*
	RS				1.00*	-0.16^{ns}	0.77^{ns}	-0.98*	-0.29^{ns}	-0.21^{ns}
	Purity			1.00*	-0.85^{ns}	0.10^{ns}	-0.68^{ns}	0.92*	-0.02^{ns}	-0.04^{ns}
	Pol		1.00*	0.92*	-0.93*	-0.13^{ns}	-0.69^{ns}	0.93*	-0.07^{ns}	-0.14^{ns}
	°Brix	1.00*	0.90*	0.66^{ns}	-0.85^{ns}	-0.36^{ns}	-0.56^{ns}	0.77^{ns}	-0.11^{ns}	-0.22^{ns}
	SA	-0.80^{ns}	-0.88*	-0.91*	0.82^{ns}	-0.87^{ns}	0.34^{ns}	-0.78^{ns}	-0.59^{ns}	-0.24^{ns}
	ASM	-0.76^{ns}	-0.95*	-0.96*	0.80^{ns}	0.16^{ns}	0.53^{ns}	-0.86^{ns}	0.23^{ns}	0.26^{ns}

Significance codes: *$(P < 0.05)$ and $^{ns}(P \geq 0.05)$ *Source*: author

°Brix (% juice)

The resistance inducers had similar effects on °Brix, since it increased in both cases, at the less concentrated AS and ASM levels, probably due to the higher efficiency in water and nutrients uptake by root system, photoassimilates synthesis and translocation, and sucrose storage on stalks, including in immature physiologically regions (Viana et al., 2017). Evaluating *Capsicum spp*. yield submitted to SA spraying, Elwan and El-Hamahmy (2009) verified a sucrose intensive mobilization from leaf in fruits using dosage equal to 1 µM. Furthermore, according to those researchers, pepper plants underwent to 100 µM doses produced fruits with lower quality, due to the SA-induced TSS reduction. Similar effect was checked by Javaheri et al. (2012), who adjusted a quadratic trend to the TSS content of *Solanum lycopersicum* fruits treated with SA, supporting results found in this study.

Sugarcane varieties are considered suitable to mechanized harvest when reach physiologic maturation degree adequate to juice production with about 15.5-16.6 °Brix (Viana et al., 2016). However, authors recommend values near or above 18.0 °Brix, due to the better juice's fermentative quality and higher ethanol yield (Inoue et al., 2015). Therefore, it was checked that levels (10 µM SA and 0.4 g ASM 100 L^{-1}) induced the SP81-3250 variety to production of juice with nearly 2.20 °Brix above standard limit (16.7 °Brix) cited on literature. Based in this inference, it was assumed that the spraying of resistance inducers dosages at earl or middle season may contributed to sugarcane tillage harvest anticipation, generating production cost saving, due to reduction of the plant exposition period to environmental adversities, such as wind, heat, water deficit, soil salinity, prolonged rainfall, and pests, factors that reduce, severely, yield of sugarcane and technological quality of its juice. Furthermore, it would be possible improves feedstock division for sugar and alcohol industrialization, since these activities are defined, mainly, from °Brix analysis (Oliveira et al., 2016).

Pol (% juice)

Pol results were attributed to two possible factors: a) synergism of less concentrated AS and ASM dosages to sucrose-phosphate synthase (PSP) and specific activities of sucrose synthase (Susy), stimulating sucrose synthesis; b) intensification of the CO_2 photosynthetic assimilation, since this gaseous substrate is essential to sucrose metabolizing. According to Rivas-San Vicente and Plasencia (2011) and Shrivastava et al. (2015), these processes usually occur on plant species treated with AS levels lower than 10 µM.

Technically, Pol analysis is very important to determination of sugarcane juice's quality, once it allows to estimate the content of apparent sucrose, organic substrate required to sugar and bioethanol industrialization (Oliveira et al., 2016). In field situation, is recommended select varieties able to produce juices with Pol content near to 14.4% (Inoue et al., 2015). Therefore, regarding to this standard limit, it was verified that levels (10 µM SA and 0.4 g ASM 100 L^{-1}) benefited sucrose content of the SP81-3250 variety´s juice in nearly two percentage point, corroborating with synergistic effects from less concentrated SA and ASM levels to feedstock quality.

Purity (% juice)

Purity is one of the most important parameter to sugarcane juice´s quality, because determine the industrial capacity of fermentable sugars recuperation, as well as bioethanol yield (Oliveira et al., 2016; Viana et al., 2016). Although this parameter is fundamentally obtained by Pol/°Brix ratio, there are others physic, chemical and mineral elements, such as heavy metals, soil colloid, sugarcane bagasse fragments, macro and micronutrients, which inappropriately affect juice's purity. For this reason, sugar-energy industry preconize feedstock with purity degree higher than 80.0%, otherwise the same is considered undesirable, mainly, when they reach values lower than 70.0%, completely restricting, material acceptation by milling sector. So, it was checked that dosages (10 µM SA and 0.4 g ASM 100 L^{-1}) provided increases of nearly seven and eight percentage point to the purity of SP81-3250 variety´s juice, respectively, regarding to standard required to sugarcane industrialization. In this sense, it was assumed that is possible offer many technique and economic advantages to sugar-energy industry, mainly, in relation to operational capacity of sucrose extraction and supply of products to the foods and biofuels markets (Oliveira et al., 2016).

RS (% juice) and TRS (% juice)

It was assumed that RS´s increase and TRS's decrease were motivated probably by stimulus originating from resistance inducers levels more concentrated than 10 µM and 0.4 g 100 L^{-1}, respectively, to acid invertases specific activity, enzymes that promote sucrose hydrolysis, generating glucose and fructose, monosaccharides that affect directly the SR and TSR relative contents in sugarcane juice physical-chemical composition (Oliveira et al., 2016).

The feedstocks highly concentrated at AR are undesirable to industrialization, because provide colour fixation to the sugars (crystal and demerara) by glucose and fructose degradation and make juice more impure, restricting fermentable sugars availability to alcohol production (Oliveira et al., 2016). In this sense, it would be preferable opt for 10 µM SA and 0.4 g ASM 100 L^{-1} dosages, which maintained the content of sugars reducing of SP81-3250 variety's juice below to critical limit (RS < 0.8%), cited on literature, culminating in TRS´s increase, source of sugars essential to the alcoholic fermentation, performed in by yeasts belonging to genus *Saccharomyces* spp. (Simões et al., 2015; Oliveira et al., 2016).

Fibres (% cane)

Results regarding to this parameter were justified by the following factors: a) of sugarcane stalks lignification process: at critical levels, resistance inducers act like signal substance to synthesis and polysaccharides deposition in cell wall, making plant tissues fibrous and, strategically, more resistant to environmental adversities; b) sucrose/fibres ratio: there is negative relation between these parameters, justifying results verified in this study, in which AS and ASM dosages lower than 20 µM and 0.8 g 100 L^{-1}, respectively, were unfavourable to the fibres content, due to positive effects provided in more proportion to juice polarization, limiting so sucrose mobilization to cell wall structuring (Jin et al., 2008; Oliveira et al., 2016).

In field condition, fibres contribute to sugarcane resistance against to physic damage caused by biotic and abiotic factors, mainly, pests and phytopathogens that attack roots and stalks, culminating in more prolonged tillage commercial cycle. Despite to advantages, fibrous varieties are not desirable to industrialization, because they limit sucrose extraction process and result in low ethanol yield. In another hand, feedstocks that present high sucrose/fibres ratio are limiting lignocellulose supply to energy cogeneration. For this reason, sugar-energy industry requires materials with fibres content near to 11.0-13.0% (Inoue et al., 2015; Simões et al., 2015; Oliveira et al., 2016). Therefore, although there were increases, it was checked out that every AS and ASM levels sprayed in SP81-3250 variety resulted in stalks with fibres percentage compatible to the standard required to sugarcane sustainable industrialization.

TSR

This parameter is influenced by many factors, including physiological maturation degree and fibres content (Teixeira et al., 2015; Oliveira et al., 2016). Usually, more fibrous sugarcane varieties show low TSR yield, supporting the results of this study, in which plants subjected to AS and ASM levels higher than 10 µM and 0.4 g 100 L^{-1}, respectively, presented lower TSR averages, due to biomass lignification induced by the elicitors at high concentrations.

TSR is indispensable to sugar-energy chain, because allows determine sucrose mass able to be turned in sugar kinds, and help to define feedstock price paid to producers (Oliveira et al., 2016; Viana et al., 2016). In this sense, AS and ASM up to 10 µM and 0.4 g 100 L^{-1}, respectively, would be more suitable to the sugarcane field management, since resulted at highest TSR yields, confirming the their potential.

Stalks and sugar yields

Several papers report that resistance inducers offer many advantages to crops, mainly, regarding to its photosynthetic characteristics. The SA exogenous spraying, for example, induce synthesis of RuBisCO (ribulose-1.5-bisphsphate carboxylase oxygenase), very important enzyme to CO_2 fixation, substrate used in the short chain carbohydrates metabolizing, such as glucose, fructose and sucrose, which affect severely technological quality of sugarcane juice (Vazirimehr et al., 2014; Simões et al., 2015; Oliveira et al., 2016). Moreover, SA and similar compounds confer to species of plants more efficiency in water and nutrients uptake, mainly, regarding to nitrogen (N), mineral element used in the synthesis of proteins, nucleic acids and chlorophylls, molecular substances essential to the sugarcane stalks growth and development of the vegetative structure, in which sucrose is storage (Jin et al., 2008; Liu et al., 2014).

SA and ASM benefits are only possible at homeostatic concentrations, otherwise, i.e., at high endogenous levels, these resistance inducers cause many negative effects to species of plants, including: photosynthetic pigments degradation, stomatal conductance reduction, cell membrane rupture, not permeability to CO_2 diffusion, cytotoxicity, and proliferation of free radicals, reactive oxygen species that they block Kalvin-Benson biologic cycle, resulting in low synthesis of phytohormones, which dramatically affect the physiological ripening and sugarcane yield, justifying results of this study, in which it was checked out that SA and ASM dosages higher than 10 µM and 0.8 g 100 L^{-1}, respectively, reduced the SP81-3250 variety agronomic performance, qualifying as phytotoxic levels to this crop (Wada & Takedo, 2010; Wada et al., 2010; Zhang et al., 2010).

Furthermore, it was assumed that SA and ASM levels till 10 µM and 0.8 g 100 L^{-1} performed similar functions to presented ones by chemical ripeners traditionally sprayed in sugarcane, triggering favourable physiological and biochemical reactions to ripening and, consequently, yield of sugar and stalks of the SP81-3250 variety. However, it is necessary more studies to confirm this interference, once there is a lack of scientific information about elicitors-induced sugarcane chemical ripening are available (Santner et al., 2009; Wolters & Jürgens, 2009). In fact, this work showed that SA levels among 20 and 500 µM are severely prejudicial to yield crop, since reduce ATP synthesis most important energetic resource to living things (Rivas-San Vicente & Plasencia, 2011).

Linear correlation

Negative associations established between the juice's parameters (Pol and purity) and resistance inducers were justified by possible antagonic effects from more concentrated SA and ASM levels to sucrose-phosphate synthase (SPS) and sucrose synthase specific activities or synergism to acid invertases, resulting in lower synthesis or sucrose degradation, respectively, generating so glucose and fructose, monosaccharide kinds that they reduce both polarization and juice´s purity degree. These linear correlations supported the juice´s quality depreciation produced by plants treated with SA and ASM levels above 10 µM and 0.4 g 100 L^{-1}, respectively. In addition, inverse correlation verified between the juice technological parameters (Pol and SR) confirmed that in fact glucose and fructose are originating from sucrose hydrolysis process (Oliveira et al., 2016). For this reason, more concentrated feedstock at SR usually present low sucrose content, justifying so results of this study, where there was Pol reduction at levels of SA and ASM above 10 µM and 0.4 g 100 L^{-1}, respectively, due to the of SR elicitors-induced at high concentrations.

The fact of °Brix and purity were associated only at ASM level showed that plant´s resistance inducers impacted, differently, in physiological and biochemical process of SP81-3250 variety, modifying the dynamic interaction between secondary metabolites of this crop. According to Vazirimehr et al. (2014), concentration and kind of inducer are two of the main factors that affect elicitors' biological activity. In general context, the correlations established between plant resistance reducers levels, juice technological parameters, and agronomic traits corroborated with regression results and literature data, since Khan et al. (2012), who evaluated correlations between sugarcane agronomic characteristics, and Tahir et al (2014), commercial varieties selection index, obtained positive linear correlations between Pol and purity, supporting citations from Silva et al. (2008), Ahmed et al. (2010), and Audilakshmi (2010), who also verified positive correlation between °Brix, Pol, and purity.

Conclusions

The salicylic acid and acibenzolar-S-methyl levels under 10 µM and 0.8 g100 L^{-1}, respectively, improved both agronomic performance and SP81-3250 variety's juice quality.

The salicylic acid and acibenzolar-S-methyl levels above 10 µM and 0.8 g100 L^{-1}, respectively, caused depreciation in technological quality of SP81-3250 variety's juice, qualifying as phytotoxic dosages to this crop.

Plant resistance inducers homeostatic levels showed potential to the sugarcane chemical ripening management.

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