Carrageenan as an eliciting active ingredient for the primary and secondary metabolism of soybeans treated with glyphosate

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ABSTRACT
Soybean is the major field crop in Brazil, currently representing 45.07% of all the temporary crops. Nevertheless, the crop constantly suffers from yield reduction due to biotic/abiotic stresses and the use of toxic substances on the fields, such as herbicides. Therefore, we aimed at using carrageenan-rich products whit the glyphosate to better the primary and secondary metabolisms of plants to reduce yield losses and to increase the bromatological parameters of the harvested grains. Overall, the use of carrageenan-rich products at different dosages and time of applications increased yields up to 13.68% and bettered the bromatological parameters of the grains.
Key-words: Carrageenan; *Glycine max*; secondary metabolism; *Solieria chordalis*.

INTRODUCTION

Soybean has been considered the major Brazilian field crop since 1998. From 1998 until 2019, the soybean harvested area increased more than 161% and its productivity and production more than 44.07 and 276.54%, respectively (IBGE, SIDRA, 2020).

Nevertheless, the crop suffers constantly from the incidence of diseases, insect-pests, competition with weeds and abiotic stresses (high/low temperatures, salinity, heavy metal concentrations, flooding, drought, herbicide, among others) (BOYER, 1982; MIRANSARI, 2016; BATTISTI et al. 2018). Boyer (1982) has shown that abiotic stresses can cause up to 69.22% of losses in soybeans, while disease, insect and weed infestations are responsible for 3.63%, 0.90% and 4.46% of yield losses, respectively. For Battisti et al. (2018), analyzing the 200 most productive areas of soybeans in Brazil for the year of 2017 came up with the conclusion that abiotic stresses and crop management (diseases, insect, weed, etc.) were responsible for 46% and 56% of the losses in soybean fields, respectively.

It is known that glyphosate also affects the development, nodulation and the productivity of soybeans due to the complexion of divalent cations such as Mn, Mg, Zn and Fe within plants causing the symptom denominated "yellow flashing" (reduction in the formation and functioning of chlorophyll), the accumulation of aminomethylphosphonic acid (AMPA), which is phytotoxic to plants, and/or direct damage of chloroplasts by glyphosate (ZOBIOLE et al. 2012).

The usage of different substances to diminish the damages caused by the use of glyphosate and the biotic/abiotic stresses suffered by soybean plants has been extensively reported in the literature (FESEL and ZUCARRO, 2016; SHUKLA et al. 2016; Chi et al. 2019). Carrageenan, for instance, is an eliciting algal sulphated polysaccharide that exerts positive effects on the primary and secondary metabolism of plants helping them to overcome stressful situations and increase productivity (SHUKLA et al. 2016).

Therefore, this study aimed at checking the development (shoot number and plant height) and productivity of soybean plants and the bromatological and mycotoxicological contents of crude protein (CP), crude fiber (CF), mineral matter (MM) end ether extract (EE) on soybean grains treated with a high dosage of glyphosate and carrageenan-rich products entitled Algomel Proact® and Seamel Pure®.

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MATERIAL AND METHODS

This study was carried out in Chapecó-SC (27°06'55" S, 52°33'53" O) with the soybean cultivar Brasmax Zeus IPRO. The sowing was held on October 8th, 2019 and the harvest happened on February 12th. Sowing density was of 250 thousand seeds per hectare with a space between lines of 45cm. The experiment was conducted under a total randomized scheme composed of five treatments and four replicates. Plots had a size of 10.0 m^2 (2.0 x 5.0 meters). The products used for the treatments were entitled Algomel Proact® and Seamel Pure®. All the treatments and application dosages can be found on table 1.

Table 1. Details of treatments and application dosages

Treatment*	Developmental stage of soybean, products and dosages used			
	V4 (November 9th)	R1 (December 26th)	R3 (January 8th)	R5 (January 21st)
01	Algomel Proact® (0.2 L/ha) Trop® Glyphosate (5.0 L/ha)	Seamel Pure® (0.1 L/ha)	Seamel Pure® (0.1 L/ha)	Seamel Pure® (0.1 L/ha)
02	Algomel Proact® (0.2 L/ha) Trop® Glyphosate (5.0 L/ha)	Seamel Pure® (0.15 L/ha)	-	Seamel Pure® (0.15 L/ha)
03	Algomel Proact® (0.2 L/ha) Trop® Glyphosate (5.0 L/ha)	SeaMel Pure® (0.3 L/ha)	-	-
04	Trop® Glyphosate (5.0 L/ha)	-	-	-
05	-	-	-	-

*All plots received fungicides and insecticides at the same rates and dates. At stage V4 all plots received Hero (80 ml/ha) + Ochima (250 ml/ha) + Cypres (300 ml/ha). At stage R1 all plots received Cypres® (300 ml/ha) + Elatus® (200ml/ha) + Ochima® (250 ml/ha) + Talisman® (250 ml/ha). At stage R3 all plots received Fox® (400 ml/ha) + Aureo® (250 ml/ha) + Engeo Pleno S® (200 ml/ha). At stage R5 all plots received Sphere Max® (200 ml/ha) + Aureo® (250 ml/ha) + Bravonil® 500 (3.0 L/ha) + Talisman® (250 ml/ha). The only products that had varied dosages and application dates were Algomel Proact®, Seamel Pure® and Trop® (glyphosate). Treatment 4 indicates the positive control (only glyphosate) and treatment 5 indicates the negative control (no glyphosate – only fungicides and insecticides).

The response variables analyzed were productivity, number of shoots per plant, plant height, CP, CF, MM and EE. For the productivity, two meters of the two central lines were harvested and measured. Number of shots and plant height were assessed on ten randomly selected plants from each plot (the same plants were used for both response variables). The assessment of CP, CF, MM and EE was performed by Labnutris® Laboratório de Análises Físico Químicas using a Perten DA7250 instrument via Near-InfraRed Spectrometry (NIRs) following the methodology PTNF-001 Rev. 00 of the Compêndio Brasileiro de Alimentação Animal and Method Number 11. All data were submitted to analysis of variance and, when significantly different, the means were compared using the Tukey's HSD statistical method at a confidence level of 5%.

RESULTS AND DISCUSSION

Algomel Proact® and Seamel Pure® are carrageenan-rich products produced from the red algae *Solieria chordalis* and used to elicit the primary and secondary metabolism of plants, as described by Shukla et al. (2016) and Chi et al. (2019). Besides having soluble Copper, Manganese, Zinc, Boron and Sulphur, Algomel Proact® and Seamel Pure® have 50% and 75% of algae extract in their composition, representing an amount of approximately 86.62 g/L and 198 g/L of carrageenan, respectively. On top of that, these products are composed of free amino acids, vitamins, more than 40 mineral nutrients coming from the algae extract, phytohormones, etc.

The productivity and, the correlation between "productivity vs. number of shoots", "productivity vs. plant height" and "plant height vs. number of shoots" is presented on Figure 1. It is possible to see that there is a very strong correlation between productivity, number of shoots and plant height, indicating that productivity is driven by the relationship that exists between plant height and number of shoots. For this cultivar (BMX Zeus IPro) and for the region where it was tested, we have found that the best plant height and number of shoots for the best productivity was

of 79.54 and 2.33, respectively. When glyphosate was applied without the use of Algomel Proact® we could see plants with the lowest height but with the greatest number of shoots, the opposite was encountered for the negative control (treatment 5).

Another important fact that was observed was that the more the application of Seamel Pure was divided (for the same final dosage) the best was the result in productivity. This goes in accordance with the eliciting capacity of eliciting materials on legumes, which are capable to elicit the secondary metabolism of plants for a period up to 10 days (STADNIK and FREITAS, 2014). By eliciting the secondary metabolism of plants we allow them to overcome stressful situations caused by the use of toxic products (pesticides), abiotic and biotic stresses, reducing the impacts on productivity (WU et al. 2017).

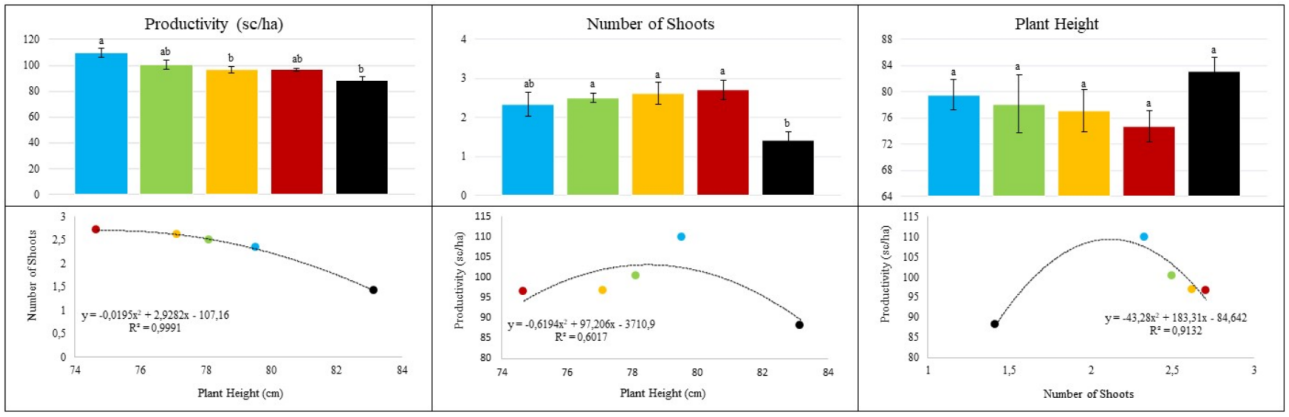

Figure 1. Productivity, number of shoots, plant height and the correlation between productivity, number of shoots and plant height for the different treatments used. We found no statistical difference for plant height (p= 0.39). However, the number of shoots (p=0.01) and productivity (p=0.01) were statistically different. Colors represent Treatment 01 (●), Treatment 02 (●), Treatment 03 (●), Treatment 04 (●) and Treatment 05 (●). Error bars represent the standard error for each treatment and variable.

For the bromatological and mycotoxicological analyses, all the results can be found on Table 2. We found no statistical difference for CP, CF, MM and EE, even though the increase in their contents was consistent to the increase of carrageenan application on the plots.

Table 2. Results on the crude protein (CP), crude fiber (CF), mineral matter (MM), ether extract (EE), for soybean grains considering the treatments presented on Table 1.

Treatment	CP (%) ± SE[1]	CF (%) ± SE	MM (%) ± SE	EE (%) ± SE
01	34.85 ± 0.13*	4.21 ± 0.12*	4.66 ± 0.06*	23.51 ± 0.33*
02	34.45 ± 0.06	4.26 ± 0.04	4.63 ± 0.02	23.41 ± 0.09
03	34.39 ± 0.16	4.33 ± 0.08	4.60 ± 0.04	23.21 ± 0.23
04	34.36 ± 0.06	4.46 ± 0.06	4.67 ± 0.06	22.78 ± 0.29
05	35.27 ± 0.51	4.47 ± 0.10	4.63 ± 0.03	22.95 ± 0.27
p-statistical	0.1131	0.3518	0.8548	0.5388

*not statistically significant according to Tukey's HSD test at a confidence level of 5%. [1]standard error.

Looking at table 2 we can see a constant improvement in the bromatological and mycotoxicological aspects of soybean grains as the application of the products were more intensive. Even though, statistically similar, small improvements in MM, CP and EE can help the industry in acquiring better end products at a lower price.

CONCLUSION

The use of Algomel Proact® and Seamel Pure® improved the yield of soybean treated with glyphosate (cultivar BMX Zeus IPro) up to 13.68% and, bettered the bromatological parameters of the grains, showing an eliciting capacity for the primary and secondary metabolisms of the plants.

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