SCAP
SOCIEDADE DE CIÊNCIAS AGRÁRIAS DE PORTUGAL

Humic substances, amino acids and marine algae extract increase sugarcane productivity

Substâncias húmicas, aminoácidos e extratos de algas marinhas aumentam a produtividade de cana-de-açúcar

Mauro Wagner de Oliveira, Vinicius Santos Gomes da Silva*, Terezinha Bezerra Albino Oliveira, Carlos Henrique de Castro Nogueira, Cícero Luiz Franco Júnior, Fabiano da Silva Brito and Gabriela Camila Silva Santos

Centro de Ciências Agrárias, BR 104, Km 85, w/n, 57100-000. Rio Largo, Alagoas, Brasil
*(*E-mail: vinicius.agro2008.1@gmail.com)*
http://dx.doi.org/10.19084/RCA17207

Received/recebido: 2017.08.20
Accepted/aceite: 2018.01.16

A B S T R A C T

The use of humic substances, amino acids and marine algae extract can help in increasing sugarcane photosynthetic and metabolic efficiency, with effects on productivity and industrial quality. In this study it was evaluated the effect of the foliar feeding of two commercial products containing humic substances, amino acids and marine algae extract, on the nutritional efficiency, industrial quality, and yield of RB867515 variety sugarcane. It was conducted in two 10.0 ha fields, with the products applied in one field and not in the other (control). The commercial products were applied in 4.0 l and 5.0 kg doses per hectare to re-growth foliage sixty days after cutting the cane-plant when the plants presented an average height of 80 cm. Ten months after applying the products, ten samples were collected from each field to assess the juice quality and sugar production. Applying the products did not influence nutritional efficiency and industrial quality, but did increase stem productivity, since the average for the control field was 126.8 kg ha^{-1}, whereas for the field where the products were applied it was 166.3 kg ha^{-1}.

Keywords: Nutritional state, industrial quality, sugar production, *Saccharum* spp.

R E S U M O

O uso de substâncias húmicas, aminoácidos e extrato de algas marinhas pode contribuir para o aumento da eficiência fotossintética e metabólica da cana, com reflexos na produtividade e qualidade industrial. Neste trabalho estudou-se o efeito da aplicação foliar de dois produtos comerciais contendo substâncias húmicas, aminoácidos e extrato de algas marinhas, sobre a eficiência nutricional, qualidade industrial e a produtividade de colmos da variedade de cana RB867515. O estudo foi conduzido em dois talhões de 10,0 hectares cada, sendo que um talhão recebeu a aplicação dos produtos e o outro não (testemunha). Os produtos comerciais nas doses de 4,0 litros e 5,0 Kg por hectare foram aplicados sobre a folhagem da rebrota sessenta dias após o corte da cana-planta, ocasião em que as plantas apresentavam altura média de cerca de 80 cm. Dez meses após a aplicação dos produtos foram colhidas dez amostras em cada talhão para avaliar a qualidade industrial e a produção de açúcares. A aplicação dos produtos não influenciou a eficiência nutricional e a qualidade industrial, mas aumentou substancialmente a produtividade de colmos, uma vez que a produtividade média do talhão testemunha foi de 126,8 kg ha^{-1}, enquanto que a do talhão que recebeu a aplicação dos produtos foi de 166,3 kg ha^{-1}.

Palavras-chave: Estado nutricional, qualidade industrial, produção de açúcares, *Saccharum* spp.

INTRODUCTION

In recent years there has been a search for cultivation practices that can help in increasing the yield and sustainability of production systems. In different sugarcane producing areas various technologies have been employed to increase input efficiency, reduce production costs, and raise soil and labor force productivity, with the aim of making the activity lucrative and sustainable. New technologies are being created that are quickly assimilated by the productive sector, such as new cane varieties, cultivation practices, crop management, irrigation and drainage, the use of more efficient equipment for extracting sugarcane juice, and industrial processes that enable more sugar and alcohol to be obtained per ton of crushed cane (Clemente *et al*., 2017; Oliveira *et al*., 2017; Silva *et al*., 2017a).

One of the most recent alternatives is the use of humic substances and marine algae extracts. Humic substances are the final products of the decomposition of organic residuals and take part in important reactions that occur in soils, influencing fertility by freeing nutrients, through the detoxication of chemical elements, by improving physical and biological conditions and by producing physiologically active substances (Canellas *et al*., 2008; Canellas and Olivares, 2014). Reports from various researchers have proven that humic substances can influence nutrient absorption, metabolism, and plant growth (Kirn *et al*., 2010; Trevisan *et al*., 2011).

These substances' main mechanisms of action in plant metabolism include their positive influence on the transporting of ions facilitating absorption, increased respiration and speed of enzymatic reactions in the Krebs cycle, resulting in greater ATP production, increased chlorophyll content, and synthesis of nucleic acids (Façanha *et al*., 2002).

In this study it was evaluated the effects of foliar feeding two commercial products containing humic substances and marine algae extract on the leaf area, nutritional state, dry material accumulation and nutrients in the aerial part biomass, stem quality, sugar production and nutritional efficiency of sugarcane RB867515 variety.

MATERIAL AND METHODS

The experiment was conducted at the Triunfo Mill located in Boca da Mata municipality in Alagoas, Brazil, where the winters are rainy and the summers are dry. When the cane fields were restored, soil samples were collected from two 10 hectare plots in which the study would later be installed. With the results from these analyses, we calculated the amount of dolomitic limestone needed to raise the soil base saturation to 60%, also adding ¼ gypsum to the lime. The soil was plowed, graded, and furrowed, with 1.00 m spacing, and then the RB867515 variety was planted. During the cane-plant cycle the two plots received the same fertilization and crop treatments.

In order to confirm that the soil fertility of the two plots was very close, soil was again collected from the 0 to 20 cm layer. Ten soil samples were collected from each field. The georeferenced samples were collected every 30 m from the field diagonal. The results from the analyses are presented in Table 1.

When the plants from the first regrowth presented an average height of around 80 cm, the humic substances, amino acids and marine algae extracts were applied in one of the plots, the other plot remained as a control. In the lot where the plants were sprinkled, we applied the products containing humic substances, amino acids and marine algae extracts (Fertiactyl GZ + KSC Mix) in doses of 4.0 liters and 5.0 kg per hectare, respectively, of the commercial products. The sprinkling was directed so that around 70% reached the leaf area and the rest reached the base of the plants.

During the maximum cane growth phase, we evaluated the leaf area and collected leaves, in triplicate to assess the plants' nutritional state. As the soil samples had been georeferenced, ten leaf area and ten leaf in triplicate collections were carried out in the same soil sample locations, each sample area measuring 2.0 linear meters. The method adopted for the leaf area evaluations was that of Hermann and Câmara (1999), which is based on linear measures of the length and width of the leaf, in triplicate, and on the number of totally open leaves and those with at least 20% green area. To evaluate the plants' nutritional state, we followed the method described by Malavolta *et al.* (1997). The foliar limb

Table 1 - Average values (mean ± standard error of the mean) for the chemical characteristics of the soil in the plots cultivated with RB867515, in the first re-growth cycle, at the Triunfo Mill, sprinkling and not sprinkling with humic substances

Chemical characteristics	pH H_2O	P	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	SB
		---mg dm^{-3}---		--------------------$cmol_c\ dm^{-3}$------------------				
Control field[1]	6.7±0.3	48±11	73±45	2.8±1.1	0.84±0.6	0,00	1.3±0.8	3.8±1.6
F + K Field[2]	6.7±0.5	29 ±11	98±53	2.7±1.0	1.1±0.4	0,00	1.7±0.6	4.0±1.3
T - test	ns	ns	ns	ns	ns	ns	ns	ns
	CEC	V	SOM	Zn	Fe	Mn	Cu	S
	$cmol_c\ dm^{-3}$	--------%-------		------------------------mg dm^{-3}----------------				
Control field	5.0±2.0	75±11	1.6±0.7	2.1±2.0	20.7±6.5	6.9±6.8	0.2±0.2	35±10
F + K Field	5.8±1.1	68±11	1.9±0.6	2.0±2.0	30.4±18	6.9±4.2	0.2±0.2	37±5
T - test	ns	ns	ns	ns	ns	ns	ns	ns

pH in H_2O (Ratio 1:2.5). P (phosphorus), K (potassium), Fe (iron), Zn (zinc), Mn (manganese) and Cu (copper): Mehlich extractor. Ca (calcium), Mg (magnesium) and Al (aluminium): KCI extractor. H+Al (hydrogen + aluminium): Calcium acetate extractor. B (boron): Hot water extractor, S (sulfur): Monocalcium phosphate in acetic acid extractor. BS (base), CEC (cation exchange capacity), V (base saturation), and SOM (soil organic matter). [1] Control field: field of sugarcane no pulverized. [2] F + K Field: field of sugarcane pulverized with humic substances, amino acids, and algae extract. ns: not differ statistically by T - test at 5% probability.

was analyzed with regards to N, P, K, Ca, Mg, S, boron, copper, iron, manganese, and zinc levels.

When the cane matured around twelve months after cutting the cane-plant, we evaluated the accumulations of dry material, industrialized stem production, and juice quality, with two linear meter plants being collected from the same points as the soil and leaf in triplicate. Again ten samples were taken from each plot.

After determining the fresh material of the entire aerial part of each sample, the vegetal material was passed through a forage shredder and dried at 65°C in a forced ventilation oven until constant mass to determine the dry material in the entire biomass of the aerial part. Another sample comprised of industrialized stems was also passed through a forage shredder, homogenized, pressed, and the juice obtained was evaluated with regards to quality, determining the apparent sucrose ("Pol"), soluble solids ("Brix"), phenol, organic and inorganic phosphor contents according to the methods described by Malavolta *et al.* (1997), and Qudsieh *et al.* (2002). Nutritional efficiency was calculated as described by Mendes (2006) and consisted of the ratio between mass of dry material and the accumulation of nutrients in the biomass of the aerial part.

The nutrients levels in the soil were determined in the chemical analysis of the 0 to 20 cm layer and the values for leaf area, nutritional state, accumulation of dry material in the entire biomass of the aerial part, apparent sucrose, soluble solids, inorganic phosphor, and phenols in the juice of the plants from the field where the humic substances and marine algae extracts were sprinkled and from the control field, were submitted for analysis of variance and the averages compared using the F test at 5% probability.

RESULTS AND DISCUSSION

Sprinkling with humic substances and marine algae extract positively influenced the length of the leaf and the number of green leaves per plant. On the other hand, sprinkling with humic substances and marine algae extract had no influence on the number of plants and the width of the leaf, which resulted in a tendency for the leaf area index (LAI) to increase ($P< 0.07$) for the plants sprinkled or not. For leaf nutrient levels, sprinkling with humic substances and marine algae extract had an effect on magnesium, sulfur, zinc, iron, copper and boron concentrations (Table 2).

The average number of plants (NP) per square meter was 10.85 (Table 2) while for leaf width an average value of 4.72 cm was obtained. Sprinkling with humic substances and marine algae extract caused increases of 7.7% in leaf length (LL) and 6.4% in the number of leaves (NL). In studies involving biometrical analyses of the aerial part of irrigated RB92579 variety sugarcane in Juazeiro – BA, Silva *et al.* (2012) observed that the greatest number of leaves per plant occurred in the period from 130 days to 300 days after cutting, obtaining an average value of approximately 8 leaves per stem. The leaf area index (LAI) values of around 4.3 obtained in this study (Table 2) are a little higher than those reported by Silva *et al.* (2017b) in studies conducted in Yellow Oxisol. This author verified that the leaf area indices for RB867515 and for RB92579 were 3.19 and 4.16, respectively.

Relatively to leaf nutrient levels, applying humic substances and marine algae extract did not alter nitrogen, phosphor, potassium, calcium and manganese concentrations (Table 2), but did cause alterations in magnesium, sulfur, boron, copper, iron, and zinc levels. For magnesium, sulfur, and zinc, the reductions were 20, 30, and 28%, respectively. On the other hand, there was a significant rise in copper, boron, and iron levels, of 35, 17, and 60%. Due to the different effect between the nutrients, these variations cannot be attributed to the dilution, but rhizosphere acidification could partly explain some results. Canellas *et al.* (2008) verified that maize plantlets treated with humic acids modify their profile of root exudation of organic acids, significantly increasing extrusion of citric and oxalic acid. This may be an explanation for the higher levels of iron and copper in the leaves, since rhizosphere acidification increases the solubility of these elements, resulting in greater absorption by the plant.

The levels of foliar phosphor, calcium, magnesium, sulfur, zinc, and iron were close to or higher than those considered adequate by Malavolta *et al.* (1997). On the other hand, a nutritional deficiency of nitrogen and potassium was found, but for copper, boron, and manganese the deficiency was even greater, thus characterizing a severe nutritional deficiency of these three microelements. The results obtained in this study are in accord with other recent studies involving different sugarcane harvests in Alagoas State (Silva *et al*., 2017b) and in the valley of Mucuri in the northeast of Minas Gerais (Oliveira *et al*., 2014), in which foliar levels of the micronutrients boron, copper, and manganese were found in lower concentrations than the minimum value cited by Malavolta *et al*. (1997) and Oliveira *et al*. (2007).

Table 2 - Average values for the number of plants (NP), leaf length (LL), leaf width (LW), number of leaves (NL), leaf area index (LAI), and nutrient concentration in the mid-third of the leaf in accord with humic substances (HS) applied

	Biometric parameters					
Treatments	**NP**	**LL**	**LW**	**NL**	**LAI**	
	Plant m^{-2}	**cm**	**cm**	**Leaf plant^{-1}**		
HS	11.40a	151.10a	4.59a	6.49a	4.42a	
Control	10.30a	140.30b	4.84a	6.10b	4.13a	
Average	10.85	145.70	4.72	6.29	4.27	
C.V	10.40	6.49	8.16	3.21	7.37	
	Macronutrient concentration in the mid-third of the leaf					
Treatments	**N**	**P**	**K**	**Ca**	**Mg**	**S**
	g kg^{-1}					
HS	17.28ª	1.58a	7.45a	3.28a	2.80b	1.58b
Control	16.92ª	1.63a	7.62a	3.80a	3.53a	2.05a
Average	17.10	1.60	7.53	3.54	3.16	1.81
C.V	9.86	5.97	12.77	53.39	8.94	10.56
	Micronutrient concentration in the mid-third of the leaf					
Treatments	**Zn**	**Fe**	**Mn**	**Cu**	**B**	
	mg kg^{-1}					
HS	19.5b	225.20a	11.60a	3.80a	6.97a	
Control	25a	140.50b	12.80a	2.80b	5.93b	
Average	22.25	182.85	12.20	3.30	6.45	
C.V	20.83	44.52	17.66	24.74	12.48	

Means with the same letter are not different by the F test ($p < 0.05$).

The concentrations of total soluble solids, apparent sucrose in the juice, purity, and recoverable sugars were close to those cited by Fernandes (2000) and Oliveira *et al.* (2014), observed in well worked plantations with a high industrial performance, and so it can be concluded that the RB867515 in the two plots was mature and the juice had good sugar levels. The inorganic phosphor level was greater than 150 mg L^{-1} (Table 3), which can be considered high, given that, according to César *et al.* (1987), in order for there to be good clarification the inorganic phosphorus level must be greater than 100 mg L^{-1} of juice.

With regards to phenol levels in the sugarcane juice, values of around 850 mg L^{-1} were obtained, similar to those observed in studies previously carried out in various sugarcane harvests in Alagoas State and in the valley of Mucuri in the northeast of Minas Gerais (Oliveira *et al.,* 2014); however, these values were around double of those reported for cane cultivated in the south central region of Brazil (Simioni *et al.,* 2006) and in Malaysia (Qudsieh *et al.*, 2002). Based on the papers from Robson *et al.* (1981), it is believed that copper deficiency is one of the causes of high phenol levels in sugarcane, since copper is a constituent of the polyphenol oxidase metalloenzyme (Robson *et al.,* 1981) and so when there is a deficiency of this enzyme there is an accumulation of phenolic compounds. As cited in Table 2, the plants had a severe nutritional deficiency of copper, boron, and manganese.

Applying humic substances increased industrialized stem production and recoverable sugars by around 30% (Table 3), even with average control plot (non-sprinkled plot) production being greater than 125 and 17.5 tons of stems and of recoverable sugars per hectare, respectively. This control production can be considered high for Alagoas State, where the maximum sugarcane growth phase coincides with short days with low luminosity, unlike what occurs in the south central region of Brazil, where an increase in luminosity occurs in the period of greatest hydric availability. The non-coincidence of maximum hydric availability and luminosity negatively influences photosynthetic rates, resulting in lower sugarcane productivity in Alagoas compared to the south central region (Oliveira *et al*., 2007).

Applying humic substances did not result in an increase of nutrient concentration in the biomass of the aerial part of the sugarcane, although there was a difference in the accumulation of nutrients in the dry material, given that sprinkling greatly increased the dry mass production of the aerial part of the RB867515. When studying nutrient exportation and extraction for different sugarcane varieties, Oliveira *et al*. (2010) obtained extraction of 237, 19, 264, 238, 90 kg of N, P, K, Ca, and Mg, respectively, adhering to the following decreasing order of extraction: K>Ca>N>P>Mg, unlike that obtained in this paper, for which the order of extraction was the following: K>N>Ca>P>Mg.

Table 3 - Average values for Brix (soluble solids), Pol (apparent sucrose), fiber, purity, PCC (apparent sucrose in the stems), TRS (total recoverable sugars), Pi (inorganic phosphor), phenols, DM accum (accumulation of dry material in the biomass of the aerial part), TCH (tons of cane per hectare), and TPH (tons of Pol per hectare)

Treatments	Brix	Pol	Fiber	Purity	PCC
	%				
HS	19.61b	16.39a	11.82b	83.45a	13.91a
Control	20.55a	16.78a	12.44a	81.49ª	14.07a
Average	20.08	16.58	12.13	82.47	13.99
C.V	4.22	6.53	3.73	2.44	6.47

Treatments	TRS	Pi	Phenols	DM accum	TCH	TPH
	kg t^{-1}	mg L^{-1}		t ha^{-1}		
HS	137.55a	158.62a	854.91a	38.825a	166.30a	22.624a
Control	139.41a	196.99a	853.21a	31.244b	126.80b	17.645b
Average	138.48	177.81	854.06	35.034.81	146.550	20.149.98
C.V	5.81	29.84	7.02	17.46	24.91	21.69

Means with the same letter are not different by the F test ($p < 0.05$).

The efficiency of N, P, K, Ca, and Mg for the accumulation of dry material and production of sucrose were not influenced by sprinkling with humic substances. When evaluating the nutritional efficiency of sugarcane cultivars, Mendes (2006) observed that the nutritional efficiency for N, P, K, Ca, and Mg of high-end RB867515 variety sugarcane was 109, 523, 51, 213, and 439 kg of TPH kg of nutrient^{-1}, respectively, (Figure 1). These results are thus similar to those of this paper in terms of the efficiency of N utilization and they differ with regards to the other macronutrients.

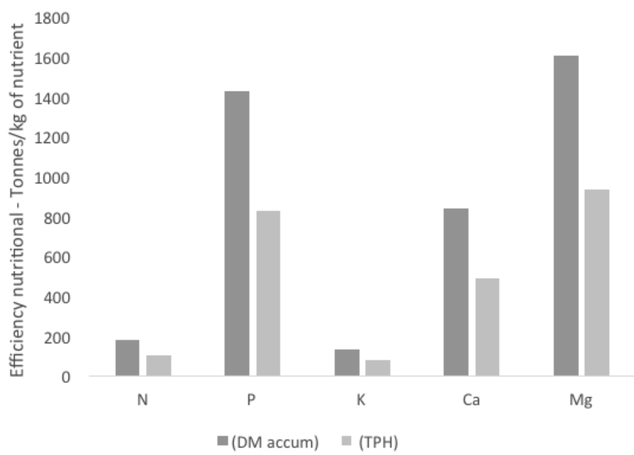

Figure 1 - Average values for efficiency nutritional for DM accum (accumulation of dry material in the biomass of the aerial part) and TPH (tons of Pol per hectare).

This study reinforces the results obtained by other researchers (Façanha *et al*., 2002; Baldotto *et al*., 2009) that the nutrient absorption kinetic is altered by applying humic substances. The higher productivity of the RB867515 in the plot that received the application of humic substances and marine algae extract was possibly the result of alterations in nutrient absorption, carbon metabolism, and nitrogen, since there was no difference between the leaf area indices for the two plots. Even without this biochemical and physiological information, this study allows to conclude that applying humic substances and marine algae extract is another technology for increasing sugarcane harvest productivity.

CONCLUSION

Applying humic substances and marine algae extracts does not alter leaf area, nutritional efficiency and industrial quality, but does increase RB867515 stem productivity, thus constituting another technology for optimizing the productive management of sugarcane.

ACKNOWLEDGMENTS

To the Triunfo Mill for the logistical support during study. To Conselho Superior de Desenvolvimento Científico e Tecnológico (CNPq) for financial support and the fellowships conceded.

REFERENCES

Baldotto L.E.B.; Baldotto, M.A.; Giro, V.B.; Canellas, L.P.; Olivares, F.L. & Smith, R. (2009) – Performance of 'Vitória' pineapple in response to humic acid application during acclimatization. *Revista Brasileira de Ciências do Solo*, vol. 33, n. 4, p. 979-990. http://dx.doi.org/10.1590/S0100-06832009000400022

Canellas, L.P. & Olivares, F.L. (2014) – Physiological responses to humic substances as plant growth promoter. *Chemical and Biological Technologies in Agriculture*, vol. 1, n. 3, p. 1-11. https://doi.org/10.1186/2196-5641-1-3

Canellas, L.P.; Teixeira Junior, L.R.L.; Dobbss, L.B.; Silva, C.A.; Medici, L.O.; Zandonadi, D.B. & Façanha, A.R. (2008) – Humic acids cross interactions with root and organic acids. *Annals of Applied Biology*, vol. 153, n. 2, p. 157-166. http://dx.doi.org/10.1111/j.1744-7348.2008.00249.x

Cesar, M.A.A.; Delgado, A.A.; Camargo, A.P.; Bissoli, B.M.A.; & Silva, F.C. (1987) – Capacidade de fosfatos naturais e artificiais em elevar o teor de fósforo no caldo de cana-de-açúcar (cana-planta), visando o processo industrial. *STAB – Açúcar, Álcool e Subprodutos*, vol. 5, p. 32-38.

Clemente, P.R.A.; Bezerra, B.K.L.; Silva, V.S.G.; Santos, J.C.M. & Endres, L. (2017) – Root growth and yield of sugarcane as a function of increasing gypsum doses. *Pesquisa Agropecuária Tropical*, vol. 47, n. 1, p. 110-117. http://dx.doi.org/10.1590/1983-40632016v4742563

Façanha, A.R.; Façanha, A.; Olivares, F.L.; Guridi, F.; Santos, G.A.; Velloso, A.C.X.; Rumjanek, V.M.; Brasil, F.; Schrispema, J.; Braz-Filho, R.; Oliveira, M.A. & Canellas, L.P. (2002) – Humic acids bioactivity: effects on root development and on the plasma membrane proton pump. *Pesquisa Agropecuária Brasileira*, vol. 37, n. 9, p. 1301-1310. http://dx.doi.org/10.1590/S0100-204X2002000900014

Fernandes, A.C. (2000) – *Cálculos na agroindústria da cana-de-açúcar*. Piracicaba: Sociedade das Técnicos Açúcareiro e Alcooleiros do Brasil. 193 p.

Hermann, E.R. & Câmara, G.M.S. (1999) – Um método simples para estimar a área foliar de cana-de-açúcar. *STAB – Açúcar, Álcool e Subprodutos*, vol. 17, n. 5, p. 32-34.

Kirn, A.; Kashif, S.R. & Yaseen, M. (2010) – Using indigenous humic acid from lignite to increase growth and yield of okra (*Abelmoschus esculentus* L.). *Soil and Environment*, vol. 29, n. 2, p. 187-191.

Malavolta, E.; Vitti, G.C. & Oliveira, S.A. (1997) – *Avaliação do estado nutricional das plantas: princípios e aplicações.* 2.ª ed. Piracicaba, Associação Brasileira para Pesquisa da Potassa e do Fosfato. 319 p.

Mendes, L.C. (2006) – *Eficiência nutricional de cultivares de cana-de-açúcar*. Dissertação de Mestrado. Viçosa, Universidade Federal de Viçosa. 46 p.

Oliveira, M.W.; Freire, F.M.; Macêdo, G.A.R. & Ferreira, J.J. (2007) – Nutrição mineral e adubação da cana-de-açúcar. *Informe Agropecuário*, vol. 28, n. 239, p. 30-43.

Oliveira, E.C.A.; Freire, F.J.; Oliveira, R.I.D.; Freire, M.B.G.S.; Simões Neto, D.E. & Silva, S.A.M. (2010) – Extração e exportação de nutrientes por variedades de cana-de-açúcar cultivadas sob irrigação plena. *Revista Brasileira de Ciências do Solo*, vol. 34, n. 4, p. 1343-1352. http://dx.doi.org/10.1590/S0100-06832010000400031

Oliveira, M.W.; Silva, V.S.G.; Reis, L.S.; Oliveira, D.C. & Silva, J.C.T. (2014) – Produção e qualidade de três variedades de cana-de-açúcar cultivadas no nordeste de Minas Gerais. *Revista Ciência Agrícola*, vol. 12, n. 1, p. 17-20.

Oliveira, D.C.; Oliveira, M.W.; Pereira, M.G.; Gomes, T.C.A.; Silva, V.S.G. & Oliveira, T.B.A. (2017) – Stalk productivity and quality of three sugarcane varieties at the beginning, in the middle, and at the end of the harvest. *African Journal of Agricultural Research*, 12, n. 4, p. 260-269. http://dx.doi.org/10.5897/AJAR2016.11789

Qudsieh, H.Y.M.; Yosof, S.; Osman, A. & Rahman, R.A. (2002) – Effect of maturity on chorophyll, tannin, color, and polyphenol oxidase (PPO) activity of sugarcane juice (*Saccharum officinarum* Var. Yellow Cane). *Journal of Agricultural and Food Chemistry*, vol. 50, n. 6, p. 1615-1618. http://dx.doi.org/10.1021/jf010959l

Robson, A.D.; Hartley, R.D. & Jarvis, S.C. (1981) – Effect of copper deficiency on phenolic and other constituents of wheat cell walls. *New Phytologist*, vol. 89, n. 3, p. 361-371. http://dx.doi.org/10.1111/j.1469-8137.1981.tb02317.x

Silva, T.G.F.; Moura, M.S.B.; Zolnier, S.; Carmo, J.F.A. & Souza, L.S.B. (2012) – Biometrics of the sugarcane shoot during irrigated ratoon cycle in the Submedio of the Vale do São Francisco. *Revista Ciência Agronômica*, vol. 43, n. 3, p. 500-509. http://dx.doi.org/10.1590/S1806-66902012000300012

Silva, V.S.G.; Oliveira, M.W.; Oliveira, T.B.A.; Mantovanelli, B.C.; Silva, A.C.; Soares, A.N.R. & Clemente, P.R.A. (2017a) – Leaf area of sugarcane varieties and their correlation with biomass productivity in three cycles. *African Journal of Agricultural Research*, vol. 12, n. 7, p. 459-466. http://dx.doi.org/10.5897/AJAR2016.11817

Silva, V.S.G.; Oliveira, M.W.; Oliveira, D.C.; Oliveira, T.B.A.; Pereira, M.G. & Nogueira, C.H.C. (2017b) – Nutritional diagnosis of sugarcane varieties in a Yellow Oxisol during three agricultural seasons. *African Journal of Agricultural Research*, 12, n. 1, p. 50-57. http://dx.doi.org/10.5897/AJAR2016.11865

Simioni, K.R.; Silva, L.F.L.F.; Barbosa, V.; Ré, F.E.; Bernadino, C.D.; Lopes, M.L. & Amorim, H.V. (2006) – Efeito da variedade e época de colheita no teor de fenóis totais em cana-de-açúcar. *STAB – Açúcar, Álcool e Subprodutos*, vol. 24, n. 3, p. 36-39.

Trevisan, S.; Botton, A.; Vaccaro, S.; Vezzaro, A.; Quaggiotti, S. & Nardi, S. (2011) – Humic substances affect *Arabidopsis* physiology by altering the expression of genes involved in primary metabolism, growth and development. *Environmental and Experimental Botany*, vol. 74, p. 45-55. https://doi.org/10.1016/j.envexpbot.2011.04.017