*Asian Jr. of Microbiol. Biotech. Env. Sc. Vol. 23, No. (3) : 2021 : 317-324*
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***ISSN-0972-3005***

# SEED TREATMENTS WITH LIPO-CHITOOLIGOSACCHARIDES ENHANCE MAIZE PRODUCTIVITY IN BRAZILEAN ENVIRONMENTS

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(Received 17 February, 2021; Accepted 15 April, 2021)

***Key words:*** *Soil microbiology, Dryland production, Integrated seed treatments, Signal molecules.*

**Abstract –** This work aimed to establish the contribution on maize (*Zea mays* L.) productivity of seed treated with a formulation containing lipo-chitooligosaccharides (LCOs) under field conditions in regions of Brazil. Five corn field trials were conducted in the Brazilian States of Paraná and Goiás. In each site, three seed treatments were established in combination with four chemical products (i) seeds without inoculation; *ii)* seeds treated with LCOs at planting; *iii)* seeds treated with LCOs 192 days before planting. Shoot and root vegetative growth and grain yield components were evaluated, and the data analyzed based on ANOVA and regression procedures. Averaged over 20 field trials, the use of maize seeds treated with LCOs promoted greater plant growth and grain production not only in response to more vigorous establishment of the plants but also keeping uniform and more active growth during their development. The mean grain yield response (390 kg ha$^{-1}$), equivalent to 4.7 % more grain production, resulted from the combined effect of the LCOs on the formation and filling of the grains.

## INTRODUCTION

Maize (*Zea mays* L.) grain yield gaps under current Brazilian production conditions, independently of the planting season, are attributed to water deficit and mainly to differences in the use recommended crop management practices (Andrea *et al*., 2018). The moderate use of intensified crop production models, and particularly those practices that provides better nutrition and growth conditions for the crops, partially explains the gaps in maize production. The use of biofertilizers is one of the pillars practices to develop high productive and sustainable modern agricultural providing tools for combined processes frequently observed in natural systems (Raffi, 2018).

The symbiosis between rhizobia and legumes and between mycorrhizae and other plants and the contribution of the use of agricultural inoculants to favor these processes is broadly documented. Diverse studies worldwide show natural benefits of these symbiosis not only related with plant nutrition but also promoting its growth (Parniske, 2008, Hungria *et al*., 2006). The lipochitooligosaccharides (LCOs) are compounds naturally produced by many soil microorganisms being functional active supporting the initiation of symbiosis relationships with plants. Several of these molecules have been also described as nod-factors when delivered from rhizobia and as myc-factors produced from mycorrhizae (Gough and Cullimore, 2011). Thus, the LCOs compounds can promote the primary actions on the plant roots of microorganisms like rhizobia and mycorrhizae. Rhizobia species will form active nitrogen fixing nodules in legumes and mycorrhizae readily form symbiotic associations also with legumes and other plant species. The symbiotic value of mycorrhizae to plants is also very well established and includes an increase in effective root surface area for nutrient uptake, nutrient access beyond the root surface, and enhanced efficiency of roots to uptake water and nutrients from the soil including nitrogen and phosphorus thereby enhancing plant growth and health (Jansa *et al*., 2003; Tanaka and Yano, 2005; Gringera *et al*., 2007).

The activity of rhizobia-produced LCOs and myc factors are closely related and parallel in activity because they evolved from common origins, with mycorrhizae developing the plant symbiotic system before rhizobia obtained the ability from mycorrhizae (Gough and Cullimore, 2011). As non-leguminous plants evolved (e.g. maize), they retained some of the molecule-detection genetics and machinery from ancestral origins that are present in legumes for association with rhizobia and LCOs. Both nod-factor LCOs and myc-factor LCOs are chemically similar and share similar recognition and response mechanisms that lead to early germination, root branching, nodulation and mycorrhization (Miransari and Smith, 2009; Gough and Cullimore, 2011; Schwinghamer *et al*., 2015). Further, LCOs produced by rhizobia can stimulate germination of mycorrhizal spores and subsequent root colonization by mycorrhizal hyphae and increase mycorrhizal colonization (Xie *et al*., 1995). The combination of LCOs to mycorrhiza allows earlier and greater pre-symbiotic activity of these organisms with the plant than mycorrhiza alone (Olah *et al*., 2005). This indirect effect can be mimicked or enhanced by coating maize seeds with both flavonoids, like genistein and deizine, and with LCOs (Smith and Osburn, 2013). Maize and soybean [*Glycine max* (L.) Merrill] field trials performed in Wisconsin (USA) showed that treating the seeds with flavonoids or LCOs increased approximately 5 % the grain productivity while the combined application of these molecules almost doubled the crop responses (Smith and Osburn, 2013).

The soils under current agricultural production conditions, mostly rotated with maize, soybean, and other crops, contain abundant rhizobia and mycorrhizal fungi in their microbiomes (Karasawa *et al*., 2002). The plants and microbes can use molecular signals to communicate (Smith *et al*., 2015a). Thus, treating maize seeds with LCOs can facilitate the initiation of symbiotic interactions during germination and the early plant growth stages. Consequently, the treated crops with this signal molecule could lead in vigorous crop establishment supporting active vegetative growth and grain production. Our objective was to measure changes in the productivity of maize crops using seeds treated with a formulation containing LCOs molecules under current Brazilian production practices.

## MATERIALS AND METHODS

During the 2017/18 growing season, five maize field trials were performed along two Brazilian States (Paraná and Goiás) covering a wide range of agricultural production environments (Table 1). In all locations, the crops were grown following best recommended practices for high productivity (Table 1) and the use of NPK(S) fertilizers (Table 2), and the preventive protection against weeds, pests, and diseases (Aguiar *et al*., 2014). The selected sites were all under long-term agriculture crop rotation, including soybean crops, and the soils mostly classified as Cambisols and Ferralsols (designated Latossolo-type soil) (Table 2). During the studied season, the mean rainfall between December to May varied between 843 and 893 mm and no limitations for normal maize growth were noted (Table 3).

In each location, the studied treatments combined three biological seed treatments [*i)* seeds without the LCOs treatment; *ii)* seeds treated with LCOs at planting; *iii)* seeds treated with LCOs before planting] with four chemical seed treatments (Table 4). The biological formulation contained 8.8 x $10^{-7}$ % in mass of LCOs in an aqueous carrier (Novozymes Inc., WI, USA) applied at a dose of 0.33 ml $kg^{-1}$ of seeds. All the chemical seed treatments were

**Table 1.** Location and main crop management practices of 5 maize field trials in the States of Paraná (PR) and Goiás (GO), Brazil.

| Sites | City, State | Latitude | Longitude | Previous crop | Hybrid | Planting date | Harvesting date |
|---|---|---|---|---|---|---|---|
| 1 | Rio Verde, GO | 17°32′35"S | 51°02′42"W | *Glycine max* | DK290PRO3 | Feb/09/2018 | Jun/30/2018 |
| 2 | Montividiu, GO | 17°15′54"S | 51°09′38"W | *Glycine max* | DK290PRO3 | Feb/09/2018 | Jun/27/2018 |
| 3 | Sta. Helena de Goiás, GO | 18°00′26"S | 50°31′02"W | *Glycine max* | DK290PRO3 | Feb/10/2018 | Jun/28/2018 |
| 4 | Aparecida do Rio Doce, GO | 18°12′11"S | 51°24′61"W | *Glycine max* | DK290PRO3 | Feb/10/2018 | Jun/28/2018 |
| 5 | Palmeira, PR | 25°25′44"S | 50°03′15′′W | *Triticum aestivum* | DK290PRO3 | Dec/02/2017 | Apr/30/2018 |

applied 192 days before planting while the LCOs formulation was sequentially applied on top of the chemically treated seeds at planting or 192 days before the planting date. The treated seeds were packed in paper bags and stored at 20° to 24°C in a dark and dry chamber with air humidity lesser than 70 % until planting.

Approximately at 30 to 35 days after emergence, at the v6 growing stage (50 % of the plants with 6 leaves completely developed, Ritchie *et al*. 1986), the stand of plants was measured counting the established plants in 3 m of the 2 central rows of each plot. Also, 5 adjacent plants located in the external rows of each plot were collected for measuring the shoot and the root dry matter. The variation in height and in shoot dry matter of the plants from the three biological seed treatments were estimated using the coefficient of variability per location calculated from 24 observations (6 field replicates and 4 chemical seed treatments).

At physiological maturity, the shoot height from the soil surface to the top of the male inflorescence

**Table 2**. Soil type and main properties (0 to 20 cm top layer) and applied fertilization treatments in 5 maize field trials in the States of Paraná and Goiás, Brazil. Soil type based on Brazilian Soil Classification System (EMBRAPA, 2018), SOM = soil organic matter, Pe = soil extractable phosphorus. Base NPK: in furrow fertilization at planting, Crop NPK(S): broadcasted fertilization during early crop growth.

| Sites | Soil type | SOM % | pH | Pe mg kg$^{-1}$ | Sand | Silt | Clay | Fertilizer | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ——— % ——— | | | Base N-P-K | kg ha$^{-1}$ | Crop N-P-K (S) | kgha$^{-1}$ |
| 1 | Latossolo roxo argiloso | 4.32 | 5.92 | 16.9 | 58 | 12 | 30 | 10-30-20 | 400 | 46-00-00 | 300 |
| 2 | Latossolo roxo muito argiloso | 4.12 | 5.32 | 18.6 | 30 | 7 | 63 | 10-30-20 | 400 | 46-00-00 | 300 |
| 3 | Latossolo vermelho muito argiloso | 4.20 | 6.1 | 22.2 | 36 | 26 | 38 | 10-30-20 | 400 | 46-00-00 | 300 |
| 4 | Neosolo arenoso | 2.7 | 5.8 | 19.3 | 87 | 10 | 3 | 10-30-20 | 400 | 46-00-00 | 300 |
| 5 | Cambissolo franco | 3.17 | 4.7 | 53 | 41.8 | 34 | 24.2 | 04-16-08 | 350 | 27-00-00 (22) | 150 |

**Table 3.** Monthly rainfall in 5 maize field experimental sites in the States of Paraná and Goiás, Brazil.

| Sites | Planting date | Rainfall (mm month$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | December | January | February | March | April | May |
| 1 | Feb/09/2018 | - | 270 | 180 | 155 | 180 | 97 |
| 2 | Feb/09/2018 | - | 265 | 198 | 169 | 136 | 109 |
| 3 | Feb/10/2018 | - | 287 | 163 | 193 | 133 | 67 |
| 4 | Feb/10/2018 | - | 291 | 193 | 158 | 149 | 66 |
| 5 | Dec/02/2017 | 232 | 330 | 79 | 250 | 2 | - |

**Table 4.** Chemical seed treatments in 5 maize field experimental sites in the States of Paraná and Goiás, Brazil.

| Seed Treatment | Fungicide | | Insecticide | |
|---|---|---|---|---|
| | Active ingredient (g.L$^{-1}$) | Dose (mL.Kg de seed$^{-1}$) | Active ingredient (g.L$^{-1}$) | Dose (mL. Kg de seed$^{-1}$) |
| A | Metalaxil-M (20),<br>Tiabendazol (150),<br>Fludioxonil (25) | 1.5 | - | - |
| B | Metalaxil-M (20),<br>Tiabendazol (150),<br>Fludioxonil (25) | 1.5 | Clotianidin (600) | 3.5 |
| C | Metalaxil-M (20),<br>Tiabendazol (150),<br>Fludioxonil (25) | 1.5 | Thiamethoxam (350) | 6.0 |
| D | Metalaxil-M (20),<br>Tiabendazol (150),<br>Fludioxonil (25) | 1.5 | Clotianidin (600),<br>Clorantraniliprole (635) | 3.52.4 |

and the perimeter of the fourth internode were measured. The grain production and the yield components (plant stand, single grain weight) were measured from the complete harvest of 8 m from the 5 central rows of each of the plots. The number of grains per unit area was estimated from the ratio between the grain yield and the single grain weight. All the grain productivity parameters were calculated at 13.5 % moisture content.

The studies were configured using a factorial (3 biological seed treatments x 4 chemical seed treatments) randomized complete block design with 6 replicates per location in 60 m$^2$ plots (10 rows with 0.5 m row spacing and 10 m long) with a separation of 1.0 m between plots.

In each of the locations the established plant stands were independent of the applied seed treatments and in none of them there were differences between the seed chemical treatments (Table 5). These results supported the use of 20 replications (5 locations x 4 seed chemical treatments) for the analysis of variance (ANOVA) of the LCOs effects on crop growth parameters integrating the diverse production and environmental conditions. Also, it favors the analysis per location based on 24 replications (6 field replicates x 4 seed chemical treatments). The differences between means were determined using the LSD test at a significance level of 0.01 (Di Rienzo *et al*. 2020). Correlation and regression analysis were calculated between selected variables and the comparison of the regression fitted lines between the mean productivity of each site (location x chemical seed treatment) and the grain yields for the biological seed treatments (Analytical Software, 2008).

## RESULTS

### Crop establishment and growth

The established populations of maize crops varied between 56,000 and 66,000 plants ha$^{-1}$ and were independent of the use of LCOs molecules in combination with the different chemical seed treatments combinations (Table 5). The application of the LCOs, in almost all the locations, did not modified the efficacy of the crop establishment (Table 5). Only in the site from Parana State the use of LCOs averaged among the 4 chemical seed treatments reduced the population in approximately 3,500 plants ha$^{-1}$ (Table 5).

**Table 5.** Summary of the ANOVA results and mean population of maize crops from seed treatments (ST) with LCOs combined with different chemistries in 5 field experimental sites in the States of Paraná and Goiás, Brazil. F values followed by * indicates p<0.05, df = degrees of freedom

| | | Experimental sites | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| | | Mean population (plants ha$^{-1}$) | | | | |
| | | 66111 | 66361 | 66222 | 66222 | 56584 |
| Source of variation | df | —————— F-value —————— | | | | |
| Chemical ST | 3 | 0.06 | 0.25 | 0.30 | 0.12 | 0.44 |
| LCOs ST | 2 | 0.17 | 0.03 | 0.02 | 0.15 | 6.25 * |
| Chemical ST x LCOs ST | 6 | 0.23 | 0.14 | 0.14 | 0.09 | 1.00 |

**Table 6.** Summary of the ANOVA results and mean parameters of vegetative growth of maize crops developed from seed treatments with LCOs applied at planting or 192 days before planting (dbp) combined with 4 chemical seed treatments in 5 sites in the States of Paraná and Goiás, Brazil. CV: mean coefficient of variability among plots, DM: dry matter, P(x): statistical probability level of the LSD mean comparison test. In each column, different letters show significant differences (p<0.05) treatments.

| | Heigth | | | | Shoot DM | | | | Root DM | | SDM:RDM | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | cm plant$^{-1}$ | | CV | | kg ha$^{-1}$ | | CV | | kg ha$^{-1}$ | | | |
| Without LCOs | 77 | B | 4,2 | A | 79 | B | 2,3 | A | 19 | B | 3,2 | A |
| LCO (at planting) | 79 | A | 3,5 | AB | 106 | A | 2,1 | A | 24 | A | 3,2 | A |
| LCO (192 dbp) | 78 | A | 3,2 | B | 93 | AB | 2,2 | A | 22 | AB | 3,2 | A |
| p(x) | 0.016 | | 0.093 | | 0.0125 | | 0.900 | | 0.0129 | | 0.545 | |

The use of LCOs molecules, averaged among chemical seed treatments and locations, enhanced the early growth of the crops. Independently if the seed treatments were applied at planting or several months before planting including LCOs favored a greater growth of the plants. Approximately 50 days after planting, at the v5-v6 growth stage, the treated crops were 2 cm taller, more uniform and with greater shoot (34.6%) and roots (26.9 %) dry matter accumulation than those without the application of these molecules (Table 6). Neither differences in the variability of the shoot dry matter accumulation nor in the relation shoot:root dry matter at v5-v6 growth stages were observed between seed treatments (Table 6).

At physiological maturity, the plants in the crops developed from the LCOs treated seeds were greater than in the control plots. Averaged over the 20 field trials. the plants were approximately 2 cm taller and the perimeter of their stalks was 3% longer (Table 7). Independently of the applied seed treatment, taller plants were observed when increasing the population of plants in each plot [Height (cm) = 138.5 + 0.0017 x plants ha$^{-1}$, $R^2 = 0.31$, n = 360].

## Grain production and yield components

At harvest, the final plant population was similar between the treatments with the LCOs molecules and there were significant differences in grain yield components and crop production (Table 7). The crops developed from the seeds treated with LCOs showed 2.3 % more grains per square meter, almost 2.5 % heavier grains and leading in approximately 4.5 % more grain production per plant than the control without the use of these molecules (Table 7). Across the 20 field trials, the maize grain yields ranged from 7335 to 9397 kg ha$^{-1}$ with 4.7 % mean response to the application of LCOs (Table 7). These benefits in grain production were observed in 90% of the field trails when the treatments were applied at planting and in 75 % of the trials with seeds treated several months before planting and independently of the chemical seed treatments applied in combination (Table 8). Based on the comparison between slopes the fitted parameters of the regression models between the grain production of the treatments and the mean of the field trials it was observed that the responses to the use of LCOs were independent of the achieved yields (Fig. 1). However, the application of the seed treatments several months before planting compared with their use at planting showed differences in the grain production among the productivity of the sites ($p<0.01$). The difference in grain production between the moments of treatments decreased when increasing the productivity of the field trials (Fig.1).

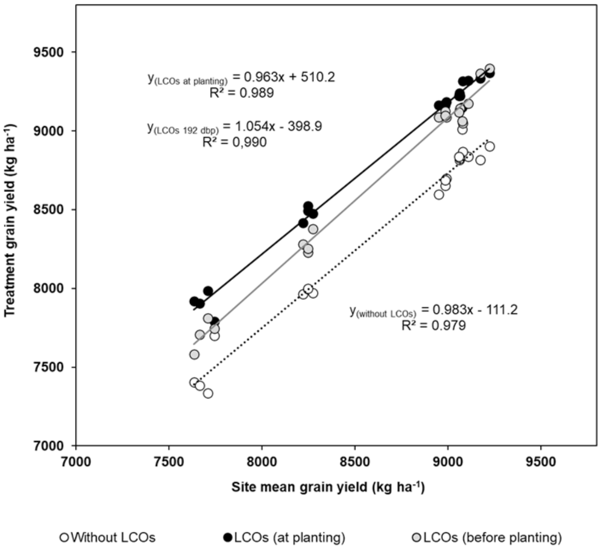

**Fig. 1.** Relationships between the grain production of maize crops (y) developed from seed treatments without or with LCOs applied at planting or 192 days before planting (dbp) and the mean production of 20 field trials planted in 5 sites in the States of Paraná and Goiás, Brazil.

**Table 7.** Summary of the ANOVA results and mean parameters at physiological maturity of maize crops developed from seed treatments with LCOs applied at planting or 192 days before planting (dbp) combined with 4 chemical seed treatments in 5 sites in the States of Paraná and Goiás, Brazil. NG = number of grains, SGW = single grain weight, P(x) statistical probability level of the LSD mean comparison test. In each column, different letters show significant differences (p<0.05) treatments.

| | Population | | Height | | Stalk perimeter | | NG | | SGW | | Grain yield | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | plants ha$^{-1}$ | | cm plant$^{-1}$ | | | | grains m$^{-2}$ | | mg grain$^{-1}$ | | g plant$^{-1}$ | | kg ha$^{-1}$ | |
| Without LCOs | 63555 | A | 248 | B | 3,3 | B | 1965 | B | 428 | C | 132 | C | 8365 | C |
| LCO (at planting) | 63524 | A | 249 | AB | 3,4 | A | 2011 | A | 442 | A | 139 | A | 8819 | A |
| LCO (192 dbp) | 63956 | A | 251 | A | 3,4 | A | 2010 | A | 435 | B | 136 | B | 8692 | B |
| p(x) | 0.489 | | 0.060 | | 0.003 | | <0.001 | | <0.001 | | <0.001 | | <0.001 | |

## DISCUSSION

The mean productivity of maize in these studies showed the frequent results observed under normal Brazilian production and environmental conditions. The grain production was strongly related with the formation and grains, however differences in the single grain weight suggested the potential limitation for crop production due to stressful conditions during the seed filling period. We observed that, under similar plant populations and environmental growing conditions, the production of maize grains was reduced when the plant growth since early stages of development was limited.

The plants developed after the application of the microbial signal molecules showed better growth since early stages supporting greater formation and filling of grains (Tables 6 and 7). These results agree with the observations that microbial driven process promote the growth of the plants and validate the contribution of LCOs also in non-legumes (Smith *et al*., 2015b). The crops treated with LCOs showed more shoot and root growth keeping a similar ratio between both parameters compared with the control without the application of this molecules. Ramos and Díaz-Zorita (2019) described more lateral root growth suggesting a difference in the resources allocation within the root systems but keeping balanced with the growth above ground. This behavior suggests that the treatments were beneficial for the overall growth of the plants and not in response to changes in the internal allocation of resources that could lead in unbalanced growth between roots and shoots. The LCOs could favored the germination (Prithiviraj *et al*., 2003) and the initiation of plant symbiosis with mycorrhizae (Gough and Cullimore, 2011; Xie *et al*., 1995) increasing and maintaining a more effective root exploration of the soil and the uptake of nutrients and other resources during the growth of the crops (Bolan, 1991). Achieving a greater number of grains per square meter in response to the application of LCOs and under similar plant populations supports a better and uniform vegetative growth conditions of the crops. While the greater single grain weight in the crops treated with LCOs, without the observation in changes in the duration of the seed filling period, also supports the fact of more active

**Table 8.** Mean grain yield of maize crops developed from seed treatments with LCOs applied at planting or 192 days before planting (dbp) in 20 field trials from the combination of 4 chemical seed treatments planted in 5 sites in the States of Paraná and Goiás, Brazil. In each row, different letters show significant differences ($p<0.10$) between treatments. Note: The identification code for the field trials within each location was randomly allocated to avoid further interpretations between the chemical seed treatments.

| | Seed treatment | | | | | |
|---|---|---|---|---|---|---|
| | Without LCOs | | LCOs (at planting) | | LCOs (192 dbp) | |
| Field trial | Grain yield (kg ha$^{-1}$) | | | | | |
| 101 | 8599 | A | 9165 | B | 9088 | B |
| 102 | 8652 | A | 9173 | B | 9128 | B |
| 103 | 8699 | A | 9186 | C | 9087 | B |
| 104 | 8689 | A | 9163 | B | 9099 | B |
| 201 | 8837 | A | 9320 | C | 9174 | B |
| 202 | 8902 | A | 9369 | B | 9397 | B |
| 203 | 8868 | A | 9319 | B | 9051 | A |
| 204 | 8816 | A | 9336 | B | 9365 | B |
| 301 | 7963 | A | 8418 | C | 8281 | B |
| 302 | 7994 | A | 8524 | C | 8228 | B |
| 303 | 7971 | A | 8476 | B | 8378 | B |
| 304 | 7998 | A | 8492 | C | 8255 | B |
| 401 | 9013 | A | 9152 | A | 9062 | A |
| 402 | 8818 | A | 9240 | C | 9128 | B |
| 403 | 8827 | A | 9225 | B | 9143 | B |
| 404 | 8836 | A | 9222 | C | 9119 | B |
| 501 | 7403 | A | 7919 | B | 7583 | AB |
| 502 | 7384 | A | 7905 | B | 7709 | AB |
| 503 | 7335 | A | 7987 | B | 7811 | B |
| 504 | 7699 | A | 7792 | A | 7746 | A |

growth during reproductive stages. The combined result of both grain yield components leads to a greater production when the crops developed from LCOs treated seeds and agreed with the observations of Smith and Osburn (2013) and Díaz-Zorita *et al*. (2010) from field studies in Wisconsin (USA) and the pampas region (Argentina), respectively. The mean grain yield contribution, approximately 5 % of the attainable grain production, was like the mean responses to the enhanced presence of microbial plant growth promoters applied to the seeds of maize crops under dryland production conditions (Cassán and Díaz-Zorita, 2016). Adding the LCOs molecules in the maize seed treatments enhanced its productivity independently of the attained mean yields (Fig.1) suggesting that the overall crop growth limitation was a regular condition along the studied environments. The mean grain yield response to LCOs tend to diminish when reducing the productivity of the field trial mostly due to less production when the treatments where applied several months before planting. The site with the lowest mean grain yields was planted late in spring and although achieved greater number of grains per square meter it showed lighter (344 mg grain$^{-1}$) single grain weight than the rest of the sites (458 mg grain$^{-1}$). These differences suggest that in this location the grain filling period happen mostly under stressful conditions with potential limitations in the capture and transformation of photosynthetic energy. We speculate that the activity of the applied molecules diminishes during their aging on the seeds due to diverse processes including oxidation and biological degradation. The projection of the daily rate of reduction on the response to the application of the LCOs (0.66 kg ha$^{-1}$) calculated from the data shown in the table 8 is expected when the molecules are applied almost until 680 days before planting.

Our results support that maize crops treated with LCOs promoted greater plant growth and grain production not only in response to more vigorous establishment of the plants but also keeping uniform and more active growth during their development. In Brazil, within the frequent dryland management production practices.

## CONCLUSION

Under current Brazilian maize production practices, the biological treatment of seeds with LCOs applied in combination with chemical compounds contributes to reduce the grain yield gap to attain high productivity. Averaged over 20 field trials, the use of maize seeds treated with LCOs promoted greater plant growth and grain production not only in response to more vigorous establishment of the plants but also keeping uniform and more active growth during their development. The mean grain yield response (390 kg ha$^{-1}$), equivalent to 4.7 % more grain production, resulted from the combined effect of the LCOs on the formation and filling of the grains.

These results support, under the tropical and subtropical regions of Brazil, the feasibility of effectively implementing seed treatment of maize with this novel biological seed treatment containing LCOs molecules providing integral benefits for the current crop production systems.

### Declaration of Conflict of Interest

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

### Authors' Contributions

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final

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