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CROP PRODUCTION

Physical and physiological qualities and productivity of corn seeds fertilized with poultry waste

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ABSTRACT: *This study evaluated the physical and physiological qualities and productivity of corn seeds, a variety UFVM 100 Native, produced in plots fertilized in top dressing with different levels of poultry waste. The experiment was organized in a randomized block design, with six treatments and four repetitions, totaling 24 plots. The treatments consisted of the application of 0.0, 1.5, 3.0, 4.5, 6.0, and 7.5 t/ha of tanned poultry waste. The seeds were subjected to the following evaluations: uniformity test, thousand seed weight, germination, vigor (first germination count, accelerated aging, soilless cold test, percentage, and emergence rate in sand), and productivity. Linear regression models were used to evaluate the effects of different dosages of poultry waste on the variables considered. The quality of seeds was not influenced by the effects of different levels of fertilization. Among the dosages used, 7.5 t/ha is recommended because it provides a greater increase in productivity, which may result in a greater financial return to the producer.*
Key words: *chicken litter, vigor, germination, organic seeds.*

Avaliação das qualidades física e fisiológica e da produtividade de sementes de milho adubado com resíduo avícola

RESUMO: *Este trabalho teve como objetivo avaliar as qualidades física e fisiológica, bem como a produtividade das sementes de milho, variedade UFVM 100 Nativo, produzidas em lavouras adubadas com diferentes níveis de resíduo avícola, em cobertura. O experimento foi instalado no delineamento em blocos casualizados, com seis tratamentos e quatro repetições, totalizando 24 parcelas. Os tratamentos consistiram da aplicação de 0,0; 1,5; 3,0; 4,5; 6,0 e 7,5 t/ha de resíduo avícola curtido. As sementes foram submetidas às seguintes avaliações: Teste de uniformidade, peso de mil sementes, germinação, vigor (primeira contagem de germinação, envelhecimento acelerado, teste de frio sem solo, porcentagem e velocidade de emergência em areia) e produtividade. Para avaliar o efeito das diferentes dosagens de resíduo avícola sobre as variáveis consideradas foram utilizados modelos de regressão linear. A qualidade das sementes não foi influenciada pelo efeito dos diferentes níveis de adubação. Dentre as dosagens utilizadas, recomenda-se a de 7,5 t/ha por proporcionar maior aumento da produtividade, o que poderá resultar em maior retorno financeiro ao produtor.*
Palavras-chave: *cama de frango, vigor, germinação, sementes orgânicas.*

INTRODUCTION

Corn has several uses, ranging from animal feed to the high technology industry (CRUZ et al., 2004). According to DUARTE (2006); although, corn is versatile in its use, its global production has accompanied the growth in poultry and pig farming.

The morphology of the corn seed is identical to that of the commercial grain. However, the seed produced for planting requires special care. Producers have a broad and demanding internal quality control system. The seed production process should comply with the laws and standards established by the Brazilian Ministry of Agriculture, Livestock and Supply (MAPA - Ministério da Agricultura Pecuária e Abastecimento) and other regulatory mechanisms, which determine minimum quality standards and control of the production process to ensure a certified seed production (ABRASEM, 2014).

Seed quality is the result of the sum of genetic, physical, physiological, and sanitary attributes that affect the seed's ability to originate

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plants with higher productivity (POPINIGIS, 1977). The four basic components of seed quality are of equivalent importance, but the physiological potential has generally received special research attention (MARCOS FILHO, 1994).

According to Normative Instruction 46, from October 6, 2011, which establishes the technical regulations and the lists of substances allowed for use in Organic Systems of Animal and Plant Production, the seeds and seedlings used for plant production must come from organic systems, which is mandatory since December 19, 2013 (BRASIL, 2011). However, supported by the results of a Public Consultation held on 17 October 2013, the Chamber of Deputies of Brazil proposed the revocation of this term, owing to the scarcity of organic seeds, to meet the certification process throughout the production chain.

Since 2016, each state can define which species and varieties must be organic. Therefore, the need to produce organic seeds and seedlings increases to meet the properties' certification requirements. The legal requirement for the organic producer to use only seeds produced in this production system and the lack of options in the market will force the demand for them, increasing the interest of several specialized companies. However, not all crops and cultivars should be produced in this system by these companies. Farmers may produce their seed mainly from local cultivars (CARDOSO et al., 2011).

The market for organic products in Brazil is expanding, and because seed is a basic input in food production, organic seeds should be made available to meet demand and legal requirements. Generally, family farmers have low technological levels and are the largest organic producers. The use of more accessible and cheaper inputs, such as poultry waste, is more feasible for these small producers (ORSINI et al., 2020).

Chicken manure is rich in organic matter, nitrogen, phosphorus, potassium, sulfur, and also provides micronutrients (MATIELLO et al., 2010). Among the types of chicken manure are hen manure and chicken litter. Studies that relate the performance of seeds in response to fertilization with poultry waste are still scarce. This waste is more used and evaluated concerning the performance and productivity of crops such as taro (ZARATE et al., 2004) and corn grain (ZARATE & VIEIRA, 2003).

Chicken litter is an organic fertilizer composed of straw with poultry feces, leftover feed, and feathers, which has good agronomic characteristics. It is generally available at low cost in the properties and has been used by producers in fertilization. Little is known about the influence of the use of chicken litter on crops and soil attributes (VALADÃO et al., 2011).

This study evaluated the physical and physiological qualities, as well as the productivity of corn seeds produced in plots fertilized in top dressing with different levels of poultry waste (chicken litter).

MATERIALS AND METHODS

The experiment was conducted in the Experimental Station of Coimbra-MG, and the experimental design used was the randomized block design, with six treatments (fertilizer levels) and four repetitions, totaling 24 experimental plots. The treatments consisted of the application of 0.0, 1.5, 3.0, 4.5, 6.0, and 7.5 tons per hectare (t/ha) of tanned poultry waste. Each experimental unit was 5.0 meters long and 4.0 meters wide, with six rows of plants. The four central rows were considered useful areas, and 0.5 meters at the ends of each row was discarded.

Corn was sown with a three-row seeder, using the open-pollinated variety UFVM 100 Native, at a spacing of 0.8 meters between rows and eight seeds per linear meter, with a total population of 60,000 plants ha^{-1}. Fertilization was not applied at planting, but only as a top dressing when the plants reached the phenological stage V2 (2 expanded leaves). Notably, the experimental area was under continuous cultivation with conventional fertilization and had received organic fertilization for the first time.

Weeds were controlled by manual weeding at the V6 stage (six expanded leaves) with the aid of a hoe. Fall armyworm (*Spodoptera frugiperda*) was controlled by applying Neen oil diluted in water at a concentration of 0.005%, and we irrigated the plants by conventional sprinkling, twice a week or when necessary, that is, on days without rain, during the vegetative stages.

The cobs were harvested and threshed manually with 17% water content. The seeds were packed in Kraft® paper packages and exposed to the sun during the day to dry to 12.5%. Pests in the seeds were killed with the product Aluphos® (aluminum phosphide) at a dose of 560 g kg^{-1} of seeds; during this process, the seeds were kept in a closed container for 72 hours. Subsequently, the seeds were stored in an environment with a temperature of 17 ± 2 °C and average relative humidity of 50% until the beginning of the analyses.

The seeds were subjected to the following evaluations: uniformity test, thousand seed weight, germination, vigor (first germination count, accelerated aging, cold test without soil, percentage and speed of emergence in sand), and productivity.

Uniformity test - a set composed of six sieves was used, arranged as follows: 14 x 3/4 oblong sieve (14 x 3/4 sieve) and 24/64" circular sieve (sieve 24), 22/64" (sieve 22), 20/64" (sieve 20), 18/64" (sieve 18), and 16/64" (sieve 16), and blind bottom. The oblong sieve was used to retain the seeds from the more rounded cob tips. A total of 3x100g of seeds/plot were sieved. The seeds retained in each sieve were separated and weighed to determine the percentage of retained seeds (BRASIL, 2009).

The following tests were performed with the seeds retained on sieves 20 and 22 because regardless of the fertilizer dose applied, there was greater retention on these sieves. Thousand seed weight (eight sub-samples of 100 seeds from each sieve) was determined according to the Rules for Seed Analysis (RAS - Regras para Análise de Sementes) (BRASIL, 2009), with the results expressed in grams.

Germination test was performed with three repetitions of 50 seeds on a roll of paper at a constant temperature of 25 ºC, according to RAS (BRASIL, 2009), and the results of normal seedlings were expressed in percent germination.

The first count was conducted together with the germination test. It involved recording the percentage of normal seedlings verified in the first count of the germination test (performed on the 4th day after sowing) (BRASIL, 2009), and the results were expressed in percentage.

Accelerated aging test was conducted with 200 seeds per plot, which were distributed on aluminum screens and fixed inside Gerbox® plastic boxes, at 41 ºC and 100% relative humidity for 96 hours (MARCOS FILHO, 1994). After this period, we followed the germination test methodology and normal seedlings were evaluated four days after sowing. Before and after aging, the water content of the seeds was determined.

Soilless cold test was performed according to the methodology described by BARROS et al. (1999).

The emergence of seedlings installed in expanded polystyrene trays (Isopor®) containing sand was evaluated. We evaluated 50 seeds sown at a depth of 1.5 cm. The evaluation was performed until emergence stabilization (eight days after sowing), and seedlings with visible plumules and at least 2 cm of aerial part were considered as emerged.

Emergence rate index (ERI): daily counts of the number of seedlings that emerged from the emergence of the first were performed considering the seedlings with visible plumules and with 2 cm of the aerial part as emerged, and the index was calculated according to Maguire (1962):

$IVE = E_1/N_1 + E_2/N_2 + ... + E_n/N_n$.

Crop productivity was estimated in kg/ha using seeds presenting 12.5% water content. The productivity was calculated by multiplying the prolificacy, obtained by the population of seedlings used, by the weight of cobs in kg.

The data were subjected to regression analysis using the *lm* function of the R Core Team (2020) software to verify the behavior of these variables in response to fertilizer levels. The models were chosen based on the significance of the regression coefficients and based on the coefficient of determination (R^2).

RESULTS AND DISCUSSION

The models that best fit the percentages of seeds retained on the 14 x 3/4 and 20 sieves were, respectively:

$$\hat{Y}_{14x3/4} = 6.97 + 4.22^{**}\sqrt{x} - 1.20^{***} x R^2 = 0.6188$$

***= significative at 5% on t test*

$$\hat{Y}_{20} = 30.13 - 0.67^{**} x R^2 = 0.6189$$

***= significative at 10% on t test"

Where $\hat{Y}$ is the dependent variable, representing the estimate of the number of seeds retained as a function of the independent variable × (levels of poultry waste).

For sieves 24, 22, 18, and 16, and seeds not retained, the best model was the mean, being 5.95, 41.88, 8.21, 6.61, and 0.44g, respectively. For the sieve 14 × 3/4, the model that best fit the data was the square root, and the estimated dose of poultry waste in which there was greater retention (10.63%) was 3.03 t/ha. As for sieve 20, the model that best fit the data was the first-degree linear model, and with the increase of 1 t/h in the dose of poultry waste, it was estimated that there was a reduction of 0.67% in the average of retained seeds. Regardless of the dose of poultry waste, the highest percentage of seeds was retained on sieves 20 and 22, with average values of 27.61% and 41.88%, respectively.

LOPES et al. (2004) reported that 87.3% of the seeds were retained on the 20 and 22 sieves and that the use of organic fertilizer on corn seeds allowed the production of larger seeds when compared to those produced in the system with mineral fertilizer. According to SATO & CÍCERO (1992), the classification of corn seeds by size is an important aspect for commercialization and mainly for sowing, because the farmer generally resists using round seeds and those of smaller size, as they suspect that they will not germinate well and will also have lower performance in the field. However, according to MARTINELLI-SENEME et al. (2001), the size of the corn seed does not interfere with its germination or vigor.

Regarding thousand seeds weight, as expected, it was reported that the seeds retained on sieve 22 were heavier than those retained on sieve 20. The first-degree linear model best fit the data for both sieves.

$$\hat{Y}_{20} = 256.01 + 1.73^{**} x R^2 = 0.6885$$
$$\hat{Y}_{22} = 315.51 + 2.71^{**} x R^2 = 0.7012$$

For sieve 20, in the absence of fertilization with poultry waste, we estimated an average seed weight of 256.01 g, and for each increase of 1 t/ha of poultry waste, we estimated an increase of 1.73 g in the average weight of seeds. For sieve 22, in the absence of fertilization with poultry waste, we estimated an average seed weight of 315.51 g, and for each increase of 1 t/ha of poultry waste, we estimated an increase of 2.71 g in the average weight of seeds.

According to Aguilera et al. (2000), uniformity of shape and size of corn seeds is extremely desirable to facilitate sowing. When evaluating the effects of shape on the physiological quality of seeds of the Pioneer 32-R21 hybrid, they reported that flat seeds had better physiological quality than spherical seeds and a higher percentage of germination. Lopes et al. (2004) reported that organic fertilizers alone did not differ statistically from organic-mineral combinations and that the treatments in which organic and mineral fertilizers were associated produced a greater thousand seed weight than the control and mineral fertilizers alone.

The effect of fertilization on thousand seed weight increased linearly, with a slight increase in seed weight for each dose increase of the fertilizer. This effect did not affect the physiological quality of the seeds, as we will discuss later.

Regarding germination percentage, the models that best fit the data for sieves 20 and 22 were, respectively:

$$\hat{Y}_{20} = 93.77 - 6.07^{**}\sqrt{x} - 1.87^{**} x R^2 = 0.8355$$

$$\hat{Y}_{22} = 94.25 - 6.97^{**} x + 0.89^{**} x^2 R^2 = 0.9016$$

These models presented a good adjustment, as the difference in the result between the highest estimate and the estimate of the control was not greater than 5%. However, according to the RAS analysis of the maximum tolerances table allowed between the results of the repetitions of the same germination test, the effect of fertilization can be disregarded, as fertilization did not show satisfactory results with respect to the percentage of germination. Nevertheless, all the values were above the minimum required for the commercialization of seeds.

The mean for germination percentage for sieve 20 was 90.39 and the standard deviation was 2.03, and for sieve 22 the mean was 86.47 and the standard deviation was 5.83 (Table 1). As fertilization did not show significant results, its use does not affect the germination percentage.

In the accelerated aging test, the seeds retained on the 20 and 22 sieves had an initial water content of 11.9%. After aging, the final water content increased to 19.5% for the seeds retained on sieve 20 and 19.4% for the seeds retained on sieve 22. According to the regression analysis, the seeds retained on sieve 20 presented a lower estimate of vigor, 84.85%, for the dose of 2.87 t/ha. We observed the highest percentage of normal seedlings, 90.44% when the dose of 7.50 t/ha was applied. The model that best fit the data for sieve 20 was quadratic:

$$\hat{Y}_{20} = 87 - 1.50^{***} x + 0.26^{*} x^2 R^2 = 0.8461$$

Evaluating the seeds retained on sieve 22, we reported that they presented the lowest estimate for vigor, 79.21%, at a dose of 1.32 t/ha, and the highest, 93.07%, for the dose of 7.50 t/ha, with similar behavior to the seeds retained on the sieve 20. The model that best fit the data for sieve 22 was the square root model:

$$\hat{Y}_{22} = 86.41 - 12.56^{**}\sqrt{x} + 5.47^{**} x R^2 = 0.9157$$

Despite the adjusted square root model, the difference in estimated vigor results between the control and the best treatment was 5%; thus, it can be concluded that there was no significant effect of the doses of poultry waste on seed vigor. However, all values were above the minimum values required for the commercialization of seeds.

The vigor mean for sieve 20 was 86.76 and the standard deviation was 2.24, and for sieve 22 the mean was 85.45 and the standard deviation was 5.26 (Table 1). As fertilization did not show significant results, its use does not interfere with vigor. According to POPINIGIS (1977), the greater the vigor, the greater the probability of survival in the field under stress conditions.

Table 1 - Mean and standard deviation (SD) of the uniformity test for each sieve, and mean and standard deviation of the tests for sieves 20 and 22.

Sieve	UT(%)±sd	G(%) ± sd	AAT(%) ± sd	SCT(%) ± sd	SET(%) ± sd	ERI± sd
14x3/4	9.51±1.68	NA	NA	NA	NA	NA
24	5.93±2.27	NA	NA	NA	NA	NA
22	41.88 ±3.08	86.47±5.83	85.45±5.26	81.47±3.91	91.33±2.91	11.27±1.29
20	27.61±2.40	90.39±2.03	87.76±2.24	82.79±1.47	95.04±1.02	11.98±0.5
18	8.21±1.41	NA	NA	NA	NA	NA
16	6.61±1.59	NA	NA	NA	NA	NA
NR	0.44±0.14	NA	NA	NA	NA	NA

UT-uniformity test; G-germination test; AAT-accelerated aging test; SCT-soilless cold test; SET-sand emergence test; ERI-emergence rate index; NA-Not applicable; NR-Non-retained seeds.

As with the soilless cold test, the seeds retained on sieve 20 presented the lowest vigor, 83.45%, at the dose of 3.47 t/ha, and the highest, 84.70%, for the dose of 7.50 t/ha. The model that best fit the data was the square root model:

$$\hat{Y}_{20} = 84.49 + 1.74^{*}x - 4.80^{*}\sqrt{x}R^2 = 0.9584$$

*=significative at 1% on t test

The seeds retained on the sieve 22 presented the lowest estimate for vigor, 76.99%, at the dose of 2.00 t/ha, and the highest vigor, 85.60%, in the absence of fertilization. The model that best fit the data was the square root model:

$$\hat{Y}_{22} = 85.60 - 10.78^{***}\sqrt{x} + 3.82^{***}xR^2 = 0.6707$$

Even after adjusting the quadratic and square root models, we can infer, in practice, that fertilization had no significant effect, because the best treatment was superior to the control by less than 2%, for both sieves. This is a minimal difference that can be disregarded, as commented in previous results.

The vigor mean for sieve 20 was 82.79 and standard deviation was 1.47, and for sieve 22 the mean was 81.47 and standard deviation was 3.91. Vigorous seeds have the potential to germinate and emerge quickly and uniformly even under adverse conditions (DIAS et al., 2010).

The cold test is considered by the International Seed Testing Association - ISTA (1981) and by the Association of Official Seed Analysts - AOSA (1983) as one of the most important in the evaluation of seed quality. According to GRABE (1976), lots of adequate quality should present at least 70% of normal seedlings as a result of the soilless cold test, values observed for all treatments in this experiment.

LOPES et al. (2004) studied the effect of organic and mineral composts, and reported that the association of organic compost and mineral fertilization resulted in better quality seeds when seeds were subjected to the modified cold test. Seeds that are grown under satisfactory conditions of nutrients in the soil are more vigorous because they supply the elements necessary for the establishment of the seedling in its initial stages (JACOB-NETO & ROSSETO, 1998).

For the sand emergence test, with the seeds retained on sieve 20, the model that best fit the data was the quadratic model:

$$\hat{Y}_{20} = 96.46 - 1.18^{**} x + 0.15^{**}x^2R^2 = 0.8282$$

The seeds presented the lowest estimate for vigor, 94.14%, at the dose of 4.06 t/ha and the highest, 96.46%, in the absence of fertilization. Despite adjusting the quadratic model, the greatest difference in estimated vigor between the control and the other treatments was around 2%, which can be disregarded. For the seeds retained on sieve 22, the model that best fit the data was the first-degree linear model:

$$\hat{Y}_{22} = 95.02 - 0.98^{*}x\ R^2 = 0.8985$$

In the absence of fertilization with poultry waste, the estimated vigor was 95.02%, and for each increase of 1t/ha in the dose of poultry waste, we estimated an average reduction of 0.98% in vigor. From the adjusted linear model, we observed the detrimental effect of fertilization. However, the greatest difference in the estimated results of emergence between the control and the worst treatment was approximately 7%. Considering the results of other quality tests, sieve 20 results, and RAS table of tolerance, fertilization can be considered without effect. The vigor mean for sieve 20 was 95.04 and standard deviation was 1.02, and for sieve 22 the mean was 91.33 and standard deviation was 2.91.

NUNES et al. (2006) observed that mineral fertilization had a beneficial effect on seedling emergence and, consequently, seedlings were more vigorous. VIANA et al. (2005) reported that corn seeds subjected to mineral fertilization had greater vigor than those without fertilization.

Considering the ERI, for the seeds retained on sieve 20, the model that best fit the data was quadratic:

$$\hat{Y}_{20} = 11.94 - 0.29x + 0.05^{**}x^2 R^2 = 0.8711$$

According to the regression analysis, it was reported that the seeds presented the lowest estimated ERI, 11.52, at the dose of 2.65 t/ha and the highest ERI, 12.25, when the dose of 7.50 t/ha was applied. Despite adjusting quadratic model, the greatest difference of estimated ERI between the control and the highest fertilizer dose was around 1.0, which in practice can be disregarded, according to the tolerance table of the RAS. For the seeds retained on sieve 22, the model that best fit the data was the first-degree linear model:

$$\hat{Y}_{22} = 12.61 - 0.36x^{*} R^2 = 0.6060$$

The estimated value of the ERI in the absence of fertilizer was 12.61, and for each increase of 1t/ha in the dose of poultry waste, we estimated an average reduction of 0.36 in this index. From the adjusted linear model, we observed the detrimental effect of fertilization. However, the greatest difference in the results of ERI estimated between the control and the worst treatment was not significant. The vigor mean for sieve 20 was 11.98 and standard deviation was 0.50, and for sieve 22 the mean was 11.27 and standard deviation was 1.29.

Considering the results of the other quality tests and the RAS tolerance table, fertilization can be considered to have no effect on ERI. Analyzing the results of germination, emergence, and vigor,we understand that the seeds from all treatments showed satisfactory quality for the market.

Fertilization with poultry waste had an increasing linear effect on productivity; the greater the dose, among those applied, the greater was the productivity. In the absence of poultry waste, productivity was estimated to be 5253.60 kg/ha, while for the highest dose (7.50 t/ha), it was 7640.85 kg/ha, with approximately a 45% increase. Silva et al. (2011) showed the potential of poultry waste as a substitute for mineral fertilizer, obtaining the greatest plant heights and largest productions of dry biomass of leaves and culms.

Figure 1 shows the graph of seed productivity with respect to the doses of poultry waste. The model that best fit the data was the first-degree linear model:

$$\hat{Y}_{PROD} = 5253.60 + 318.30^{**}x\ R^2 = 0.7781$$

Considering the significant increase in corn seed productivity with the increase of fertilization doses of poultry waste, the price of organic corn seed in the

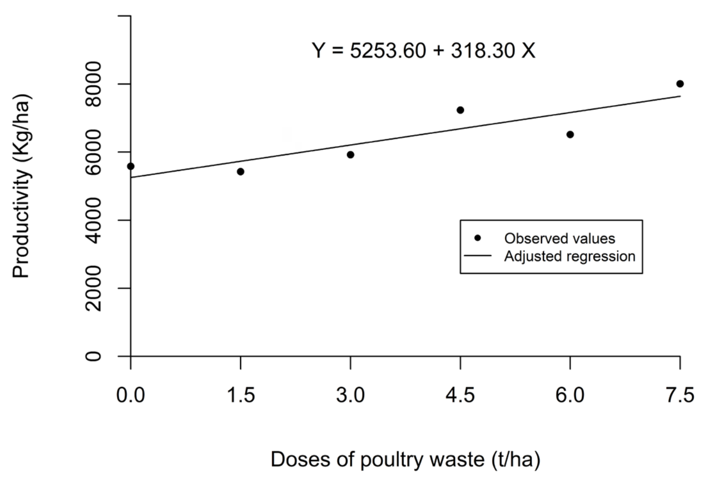

Figure 1 - Corn seed productivity with respect to doses of poultry waste.

market, and the expenses with low-cost fertilizer, the financial return that fertilization with poultry waste can provide in the production of this input is evident.

CONCLUSION

Fertilization with poultry waste did not affect the physical and physiological qualities of the seeds. However, on increasing the doses of poultry waste, productivity increased significantly.

Considering conditions like those of this study, for the physical and physiological qualities of the seeds, fertilization with poultry waste is not necessary; however, if the objective is to increase productivity, the dosage of 7.5 t/ha is recommended because it provides a greater increase, which could result in a greater financial return to the producer.

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DECLARATION OF CONFLICT OF INTEREST

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

AUTHORS’ CONTRIBUTIONS

All authors contributed equally to the design and writing of the manuscript.

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