THE INFLUENCE OF AQUASORB ON SOIL MOISTURE AND SOME MORPHO-PHYSIOLOGICAL PROPERTIES IN MAIZE CROP

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Abstract

The influence of Aquasorb on soil moisture and some morpho-physiological properties (average plant height and leaf chlorophyll content) was studied in maize cultures. Aquasorb is a copolymer of acrylamide and potassium acrylate, which works in absorption-desorption cycles of water and nutrients. During humid periods, it significantly increases its volume, becoming largely expanded, and during droughts it releases water and plant nutrients. In the global climate change context, agrotechnical problems such as water retention in the soil are becoming more and more frequent and, therefore, the use of a hydrogel can be a measure with beneficial implications for the agricultural sector. The experiment was carried out in vegetation vessels with a volume of 6 l, in which four variants were placed: V_1 (control, untreated) and V_2 (treated with 20 kg ha^{-1} of Aquasorb) under normal climatic conditions and variants V_3 (without treatment) and V_4 (treated with 20 kg ha^{-1} of Aquasorb), which were subject to water stress. It was induced by plants (in V_3 and V_4) by reducing the number of waterings by half compared to variants V_1 and V_2, from the 4-6 leaf stage in maize. The hydrogel treatment was performed at sowing depth (8-10 cm for maize), together with the application of complex fertilizer. The results showed that, in optimal humidity conditions, plants do not make use of the positive effect of the hydrogel, but in water stress conditions, Aquasorb is used in the agricultural sector, at least for maize crops, possibly for other crops.

Key words: Aquasorb, Maize, morphological properties, soil moisture

Aquasorb is a hydrogel derived from polyacrylamide (PAM) and potassium acrylate. Hydrogels may offer benefits to the environment due to their action on soil and plants (Claire Farrell, *et al*. 2013; Sepaskhah A.R., *et al.*, 2006; Sepaskhah A.R. and Mahdi-Hosseinabadi Z., 2006; Peterson D., 2009; An Li, *et al.,* 2005) by retaining important volumes of water (Hany El-Hamshary, 2007). Hydrogels application may stabilize the soil structure, increase the erosion resistance and the infiltration rate and may decrease the surface drain (Sojka R.E., 2007; Santos F.L., Serralheiro R.P., 2000; Jihoon Kang, *et al*., 2015; Santos F.L., *et al.*, 2003; Sepaskhah A.R. and Shahabizad V., 2010; Assaf Inbar, *et al*. 2015). The soils with high content of sodium- or calcium-carbonate may present low drainage due to the stagnant water that will induce a poor aeration at root level with subsequently reduced productivity (Abu-Hamdeh, N.H., 2004; Rashad A. Hussien, *et al.,* 2012). Aquasorb administration may solve these kinds of inconveniences due to its absorption-desorption working cycles (of water and nutrients), depending on the soil conditions (moisture or drought). In arid or semiarid areas, Aquasorb proved to be efficient in increasing the water retention capacity, decreasing the infiltration rate and cumulative evaporation and increasing the water conservation (Rifat Hayat and Safdar Ali, 2004). The plants cultivated on soils treated with Aquasorb had more available water for longer periods of time, which lead to lower irrigation frequency (Sharma J., 2004). Generally, its efficiency is decreasing in time as proved by the significant reduction of water retention capacity after 18 months from administration on soil (Holliman P. J., *et al.,* 2005). However, in normal climatic conditions, the acrylamide resulted from PAM degradation, does not exceed the legal concentrations (ToxGuideTMforAcrylamideC3H5NO,CAS#79-06,U.S.)

At present, many scientific studies present controversial information on the efficiency of administering hydrogels on other types of soil besides the sandy ones (Nevenka Đurović, *et al.,* 2012). In most of these studies, the registered variations can be determined either by certain properties of hydrogels or other factors, so that in order to complete this

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database with regard to the administration of hydrogels in the agricultural sector, we conducted this study in which we analyze the efficiency of Aquasorb on another type of soil besides the sandy ones. In addition, the usefulness of this study is shown especially in the context of global climate changes, in which the distribution of rainfall, at least in the impact area of the study, is not uniform, with deviations from their multiannual average. We consider that this general picture is an important argument for conducting this study, as a result we will determine the extent to which the hydrogel Aquasorb can be another efficient agrotechnical solution for the retention of water in soil.

MATERIAL AND METHOD

The experiment was carried out in vegetation vessels with a volume of 6 l, in which four variants were placed: V_1 (control, untreated) and V_2 (treated with 20 kg ha^{-1} of Aquasorb) under normal climatic conditions and variants V_3 (without treatment) and V_4 (treated with 20 kg ha^{-1} of Aquasorb), which were subject to water stress. It was induced by plants (in V_3 and V_4) by reducing the number of waterings by half compared to variants V_1 and V_2, from the 4-6 leaf stage in maize. The hydrogel treatment was performed at sowing depth (8-10 cm for maize), together with the application of complex fertilizer Eurofertil Plus PHOS 38 (3.2 g per vase).

The moisture of soil (U, %) was determined on soil samples taken from a depth of 0-5 cm, 5-10 cm and 10-15 cm, in aluminum phials that were dried in the oven at a temperature of 105 Celsius degrees until constant weight. The moisture of soil was calculated by referencing the weight of water from the analysed sample (m_1) to the weight of complete dried soil (m_2), according to the relation suggested by Dumitru Elisabeta *et al.,* 2009 (1):

$$U\%_g = \frac{m_1}{m_2} \times 100 \qquad (1)$$

where: m_1 – the weight of water from the analyzed sample (g); m_2 – the weight of soil dried in the oven at 105 Celsius degrees (g).

In order to better understand the way in which Aquasorb treatment influences soil moisture, it was determined both immediately after watering (beginning of August) and before watering (end of August).

The *chlorophyll content in leaves* was measured using the CCM 200 plus device from Opti-Science Company (*Figure 1*).

It is a tool for measurements performed in the experimental field and makes precise, reliable and easy chlorophyll content determination of leaves. The device can store 4000 measurements performed with a detector with two photo-diodes with absorbance amplifier.

Figure1 **Device used for determining the chlorophyll content of leaves** *(http://www.marconi.com.br)*

Determinations were made in the upper third of the plants, in the middle thereof and in the lower third, in order to highlight more clearly the way in which the plant growth is influenced by the Acuastoc treatments. The device records the data in the internal memory, which are then downloaded to the PC, where they were processed using the ANOVA and the F test.

In order to determine the *average height* of the plants, measurements took places 30 days after the sowing, during the period of vegetation and harvesting, for each variant in 6 repetitions.

RESULTS AND DISCUSSIONS

Influence of Aquasorb on soil moisture

The moisture of soil is one of the factors that intervene and affect the quality and concentration of soil solution. In the context of a very diluted soil solution, there are serious physiologic imbalances in soil fertility, while in a soil solution balanced in terms of soil solution concentration and quality, soil fertility is high and plants grow and develop in optimal conditions. Most of the nutritious elements found in the soil solution are also found in the plant, so that plants can optimally turn them to good account only if a soil moisture balance is ensured.

Due to the morphology of maize, which has a very profound root system, it adapts to short periods of drought, especially during the first part of the vegetation period (Aldrich S. *et al.*, 1975, quoted by Muntean L.S. *et al.*, 2003), which affects its production capacity. It was shown that each day of drought for maize (drought meaning less than 50% soil moisture according to the active moisture index), causes a reduction of production by 90 kg ha^{-1} grain maize in intensive cultures (Lăzăroiu A. *et al.*, 2008).

The analysis of experimental results showed that Aquasorb has a direct influence on soil moisture, with statistically significant differences between the treated variants and the witness variant, both in relatively optimal conditions of humidity, but especially in condition of water stress.

The obtained results revealed that immediately after watering (beginning of August), soil moisture varied within limits from 0 to 15 cm in depth, with values that are slightly higher in the layer 5-10 cm both in relatively optimal humidity conditions and in water stress conditions (*Figure 2*). In the less favorable conditions recorded before watering (end of August), significant fluctuations in water distribution were noticed in 0-15 cm of depth. Thus, the greatest fluctuations appeared in the V_1 untreated variant in the 5-10 cm layer and V_3 in the 0-5 cm layer, while in the V_4 variant treated with Aquasorb, soil moisture increased progressively with depth (*Figure 2*).

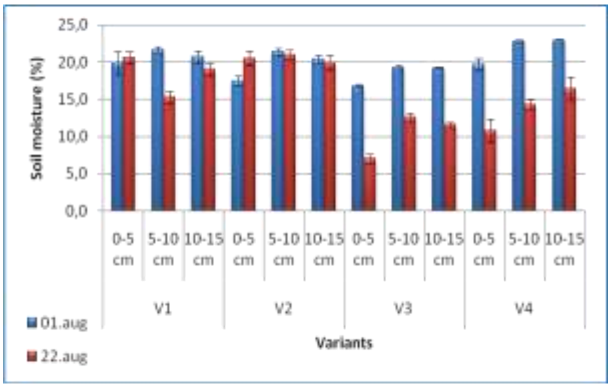

Figure 2 **The influence of Aquasorb on the soil moisture in maize crop**

(V_1 - untreated (control); V_2 – 20 kg ha^{-1} Aquasorb; V_3 - untreated, hidric stress; V_4 - 20 kg ha^{-1} Aquasorb hidric stress)

In terms of average moisture in the depth 0-15 cm, the hydrogel Aquasorb significantly influenced soil moisture differently, depending on the active moisture index. Thus, when optimal moisture was provided, immediately after watering (1st of August), soil moisture was 1% higher in the V_1 witness variant compared to the V_2 treated variant, in which moisture was 19.8% (*Figure 3*).

This aspect can be explained through the fact that in the case of the variant treated with Aquasorb, it retained a quantity of water as a supply that becomes accessible to plants whenever the moisture of soil falls below a certain threshold. In other words, this situation showed the competition for water between hydrogel and the plant roots, an aspect that could be studied in a future research project. In addition, in the case of the V_4 (treated with Aquasorb and subjected to artificially induced periods of water stress), moisture was recorded to be by 2% higher compared to the V_1 untreated variant and by 1% compared to the V_2 variant (treated with Aquasorb but in relatively optimal conditions of humidity). In order to explain this aspect, we will take into consideration that the treatment with Aquasorb influences the total porosity of soil, in the sense that the variants treated with Aquasorb showed lowered values whenever a balanced level of soil moisture was ensured (Galeş D.C. *et al.*, 2016). In the light of these pieces of information, we can appreciate that in the case of the V_4 variant, due to the periods of water stress, the level of total porosity was influenced in a differentiated way, which also indirectly influenced the capacity of soil to retain water.

When an optimal active moisture index is not ensured, which is before watering (the 22nd of August), it was clearly noticed the positive influence of the treatment with Aquasorb and at the same time the utility of using it in the agricultural sector. Thus, it will increase the efficiency of using water and at the same time it delays the appearance of the critical threshold for drought. The results confirming this aspect show a soil moisture increase in the treated variants in comparison with the untreated ones by 2.1% in relatively optimal conditions of humidity and by 3.4% in conditions of induced artificially water stress (*Figure 3*).

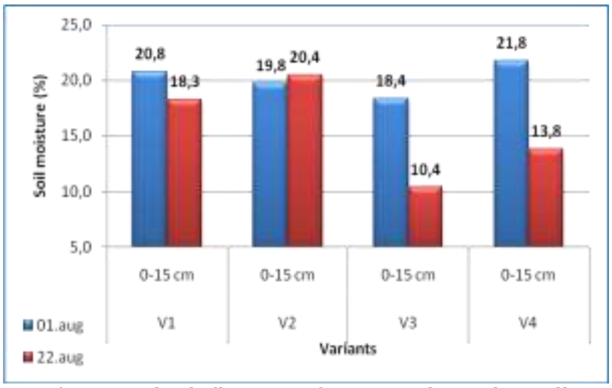

Figure 3 **The influence of Aquasorb on the soil moisture in maize crop (mean values 0-15 cm)**

(V_1 - untreated (control); V_2 – 20 kg ha^{-1} Aquasorb; V_3 - untreated, hidric stress; V_4 - 20 kg ha^{-1} Aquasorb hidric stress)

Figure 4 shows the values of average soil moisture over the entire vegetation period. They point out that, in relatively optimal conditions of humidity, lower levels of moisture were noticed in the 5-10 cm layer and higher and with relatively similar values in the 0-5 cm layers and 10-15 cm respectively in the V_1 variant (not treated), while in the variant treated with Aquasorb the situation was completely different, with highest values of soil moisture in the 5-10 cm layer, the depth where the hydrogel is incorporated (*Figure 4*).

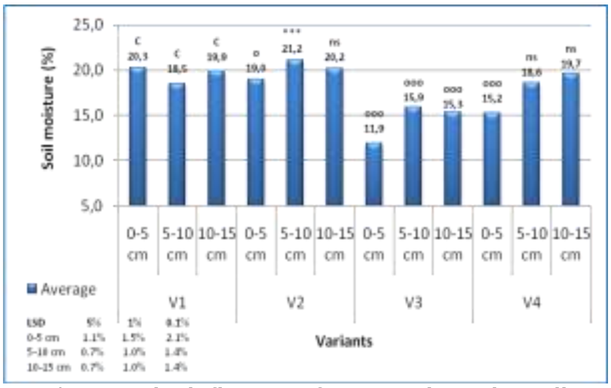

Figure 4 **The influence of Aquasorb on the soil moisture in maize crop (mean value on growing stage)**

(V_1 - untreated (control); V_2 – 20 kg ha^{-1} Aquasorb; V_3 - untreated, hidric stress; V_4 - 20 kg ha^{-1} Aquasorb hidric stress)

*LSD – Least Sighificant Difference; C – control; ns – insignificant; *** - very significant; o – negative significantly; ooo – negative very significant.*

In conditions of water stress, it was noticed that soil was much drier in its upper part (0-5 cm), and below this depth, its moisture was about 15% in the V_3 variant. In the V_4 variant, soil moisture increased progressively with the depth, reaching 18.6% in the 5-10 cm layer and 19.7% in the 10-15 cm layer (*Figure 4*).

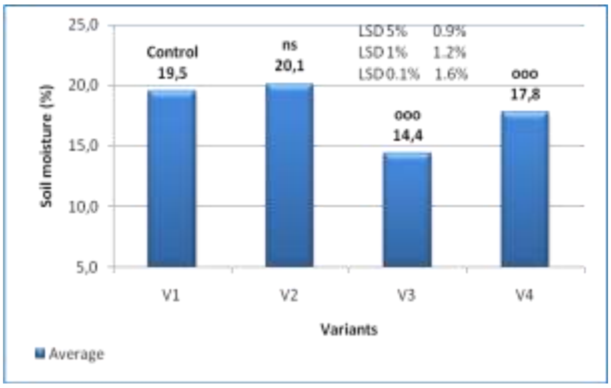

Figure 5 **The influence of Aquasorb on the soil moisture in maize crop (mean value on depth and growing stage)**

(V_1 - untreated (control); V_2 – 20 kg ha^{-1} Aquasorb; V_3 - untreated, hidric stress; V_4 - 20 kg ha^{-1} Aquasorb hidric stress)

LSD – Least Sighificant Difference; ns – insignificant; ooo – negative very significant.

The influence of Aquasorb on chlorophyll content in leaves

The chlorophyll content in leaves was determined taking into consideration the morphology of the plant. This parameter was measured in the top, middle and bottom third internode above the soil. The average height of the plant was also measured, as water deficiency during the stage of quick stem growth reduces the plant growing rate, foliar surface and chlorophyll content in leaves. The floral organs are also affected, as the number of fertile flowers on the cob diminishes, which finally leads to a decrease in production. During this stage, by maintaining soil moisture under the threshold of 50%, production decreased by 59% (Lăzăroiu A. *et al.*, 2008).

The results emphasized that in relatively optimal conditions of humidity, the middle third had the lowest chlorophyll content in leaves in the V_1 untreated variant (13.1 Chlorophyll Content Index - CCI), while the treatment with Aquasorb contributed to the significant increase in the chlorophyll content in leaves at the medium part of the plant (14.3 CCI) and the reduction of chlorophyll content in the top and the lower third down to 13.0 CCI and 12.6 CCI respectively (*Figure 6*).

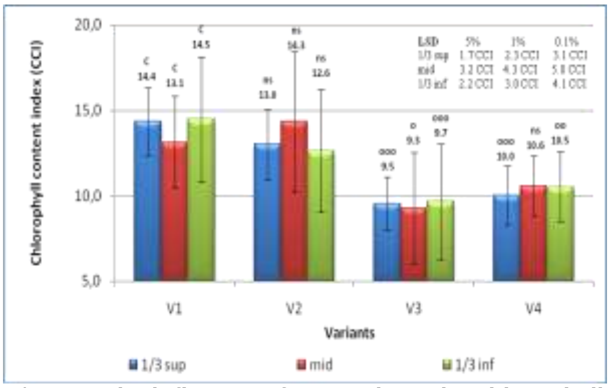

Figure 6 **The influence of Auasorb on the chlorophyll content in maize**

(V_1 - untreated (control); V_2 – 20 kg ha^{-1} Aquasorb; V_3 - untreated, hidric stress; V_4 - 20 kg ha^{-1} Aquasorb hidric stress)

LSD – Least significant difference; C – Control; ns – insignificant; o – negative significantly; oo – negative distinctly significant; ooo – negative very significant.

In conditions of water stress, the differences recorded between plant parts reduced, with an amplitude of variation between them of 0.4 CCI in the V_3 untreated variant and of 0.6 CCI in the V_4 treated variant (*Figure 6*).

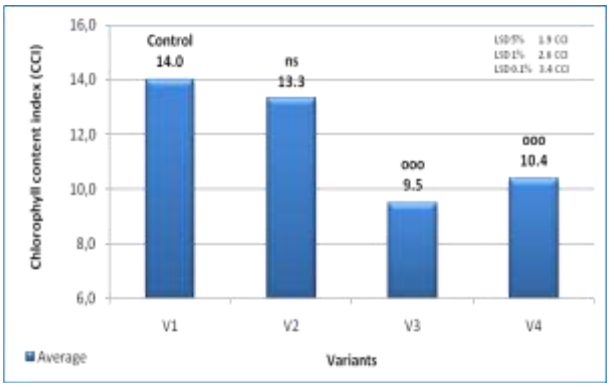

Figure 7 **The influence of Auasorb on the chlorophyll content in maize (average on the plant)**

(V_1 - untreated (control); V_2 – 20 kg ha^{-1} Aquasorb; V_3 - untreated, hidric stress; V_4 - 20 kg ha^{-1} Aquasorb hidric stress)

LSD – Least significant difference; ns – insignificant; ooo – negative very significant.

The average chlorophyll content on the plant shows that the treatment with Aquasorb is efficient especially for conditions of water stress. In this respect, in relatively optimal conditions of humidity, it was indicated a competition for water between Aquasorb and the plant roots, so that in the case of the untreated variant, the average chlorophyll content in leaves was higher by 0.7 CCI compared to the V_2, which reported 13.3 CCI (*Figure 7*). In conditions of water stress, the average chlorophyll content in leaves increased by 0.9 CCI in the V_4 treated variant in comparison with the V_3 untreated variant, which reported 9.5 CCI (*Figure 7*).

The influence of Aquasorb on the average height of plants

The average height of plants is directly proportional to soil moisture. The size of the plant was higher in plants treated with Aquasorb at all vegetation stages during which this parameter was determined. About 40 days after the sowing, when water stress had been already induced by reducing the number of waterings, the size of the plants was 2.9 cm higher in the plants treated with Aquasorb in relatively optimal conditions of humidity and 2.7 cm higher in conditions of water stress (*Figure 8*).

In addition, there were noticed differences between variants depending on vegetation conditions as well. Thus, water stress contributed to the plant size reduction about 40 days after sowing by 0.7 cm in the untreated variants and by 0.9 cm in variants treated with Aquasorb (*Figure 8*). This tendency was also noticed during the other stages of vegetation, during which the differences were of 34.8 cm in the untreated variants and 28.5 in the treated variants at the end of July, and towards the end of August, the differences were of 16.3 cm in the untreated variants and 13.5 cm in the variants treated with Aquasorb (*Figure 8*). An analysis of these results shows that in the variants treated with Aquasorb, the size of plants is less influenced by water stress, in comparison with the variants that did not undergo the treatment. By analyzing the results in a differentiated way on the conditions of vegetation, it was noticed that, during all stages of growing, plants had a higher size in the treated variants in comparison with the untreated ones, and the biggest differences were noticed in July, reaching 4.5 cm in relatively optimal conditions of humidity and 10.8 cm in conditions of water stress (*Figure 8*).

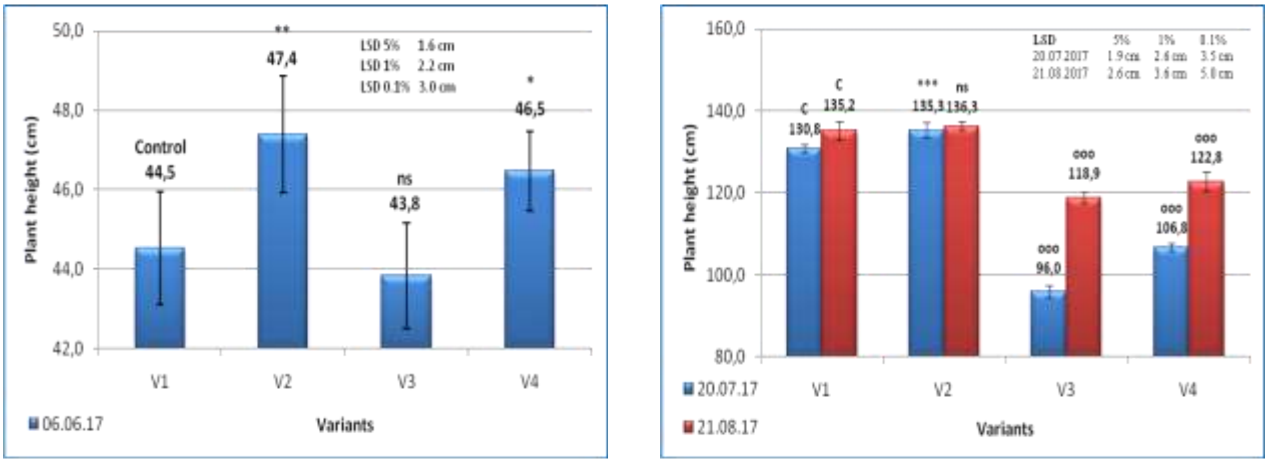

Figure 8 **The influence of Aquasorb on the average plant height in maize**

(V_1 - untreated (control); V_2 – 20 kg ha^{-1} Aquasorb; V_3 - untreated, hidric stress; V_4 - 20 kg ha^{-1} Aquasorb hidric stress)

*LSD – Least significant difference; C – Control; ns – insignificant; * - significant; ** – distinctly significant; o – negative significantly; ooo – negative very significant.*

The analysis of average values over the entire period of vegetation shows that the treatment with Aquasorb contributes to the increase in the size of plants both in optimal conditions of humidity, but especially in conditions of water stress. It is to be noted that, from an economic point of view, it is justified the administer it especially in conditions of water stress. The statistical differences between the treated variants and the untreated ones were of 2.8 cm in relatively optimal conditions of humidity and 5.8 cm in conditions of water stress (*Figure 9*).

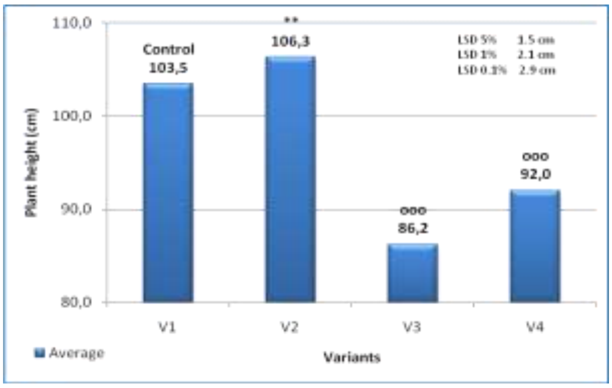

Figure 9 **The influence of Aquasorb on the average plant height in maize (mean values on growing stage)**

(V_1 - untreated (control); V_2 – 20 kg ha^{-1} Aquasorb; V_3 - untreated, hidric stress; V_4 - 20 kg ha^{-1} Aquasorb hidric stress)

*LSD – Least significant difference; ** – distinctly significant; ooo – negative very significant.*

CONCLUSIONS

The treatment with Aquasorb contributed to increased soil moisture by 0.6% in relatively optimal conditions of humidity and by 3.4% in conditions of water stress. In addition, the average chlorophyll content in leaves decreased by 0.7 CCI in relatively optimal conditions of humidity, while it increased by 0.9 CCI in conditions of water stress, and the size of plants was higher by 2.8 cm in relatively optimal conditions of humidity and by 5.8 cm in conditions of water stress.

These results show that Aquasorb treatment, at a dose of 20 kg ha^{-1}, can be used successfully in maize culture.

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