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Hydrogel effect on growth and development of tomato seedlings

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Abstract
As hade-house experiment was conducted at Africa University, Mutare, Zimbabwe to evaluate the effect of hydrogel addition in pine bark (growing media) on the growth and development of tomato seedlings when subjected to moisture stress conditions. The experiment was laid out in a complete randomized design (CRD) having four treatments with three replicates as follows: Treatment A (1 hydrogel capsule), treatment B (2 hydrogel capsules), treatment C (3 hydrogel capsules) and treatment D which was the control having no hydrogel capsules added. The obtained results showed that the application of 1, 2 and 3 hydrogel capsules had a positive effect on the growth and development of tomato seedlings. The addition of hydrogel capsules promoted water and nutrient retention which explains why the effects of moisture stress and leaching were at a minimal as compared to the control. Treatment C had the best performance in all measured parameters mainly because the capsules added could retain more water and nutrients as compared to all the other treatments. Hydrogel can be a game changer in the seedling production of tomatoes through its climate proofing mechanism securing the future of seedling production in water limited environments. However, further experiments are to be conducted with 4, 5 and 6 hydrogel capsules to validate that 3 hydrogel capsules give the best results. Further experiments will help in knowing the number of capsules to apply for the best performance until they begin to have a detrimental effect on the growth and development of the tomato seedlings. Data was collected and recorded in Microsoft Excel and subjected to statistical analysis using one-way Analysis of Variance (ANOVA). Differences between means were determined using the least significant difference (LSD) test at P = 0.05% level. The findings were presented in the form of clustered and bar graphs which had polynomial trend lines and equations.

Keywords: Climate change, water scarcity, hydrogels, moisture retention, tomato growth and development, sustainable agriculture

Introduction

In this era of climate change. Water scarcity has become the defining crisis of our time which has threatened the agricultural industry. This has resulted in the designing of water-conserving technologies to minimise water wastage. Hydrogels have been on the rise as a water-conserving technology having the capacity of absorbing water that will be released only when the environment around the root zone begins to dry out. This mechanism will prevent plants from experiencing moisture stresses which can have a negative impact on plant growth and development. They are a sustainable water-conserving technology with the ability of minimising fertiliser and water applications thereby cutting down on fertiliser and electricity costs. Lastly the future of farming is bright if these superabsorbent polymers are harnessed especially in the arid and semi-arid regions as they can significantly increase crop and seedling production minimising food insecurities.

When the moisture, light, and temperature conditions are favourable, seed germination occurs, followed by the formation of radicle, hypocotyl, and cotyledons. To begin photosynthesis, the seedling develops a root system and leaves (Maximum yield, 2018) [10]. Water is a vital natural resource that supports plant life and growth, but there is growing concern about its scarcity (Mng'omba, Akinnifesi, Sileshi, Ajayi. Nyoka, Jamnadass, 2010) [12]. During dry seasons, as rivers, streams, shallow wells, and boreholes dry up, this challenge becomes enormous (Mng'omba *et al*, 2010) [12].

A germinating seed's slow water absorption may jeopardize its emergence and subsequent crop stand (Sghaier, Tarnawa, Khaeim, Kovacs, Gyuricza and Kende, 2022) [15]. Furthermore, when seedlings lack water, they wilt, and if this occurs for an extended period of time, plant cells become fully defaulted, resulting in seedling death.

Due to a lack of water, photosynthesis is also reduced. Photosynthesis can be slowed or stopped in plants. Internal food supply is reduced, and plant leaves begin to yellow in most cases. Transpiration is also inhibited or slowed, causing the plant to perish from top to bottom (Airowater, 2020) [1]. The global availability of fresh water is projected to drop to 5100 m^3 per capita per year by 2025 (Shiklomanov, 1999, 2nd Edition, 2008) [17].

The incorporation of hydrogel technology in seedling production has the potential to significantly reduce water scarcity because these polymers can absorb, store, and release water. Water is absorbed from the soil and stored until the area surrounding the root zone dries out. Hydrogels can protect soils from runoff flow, improve fertilizer performance, and increase microbial activity in the soil. Hydrogels do not work in areas with high rainfall distribution. The use of these hydrogels is a form of sustainable precision farming as farmers will be able to produce more using less water. The effectiveness is determined by soil texture, polymer type, method and time of application, and crop species (Patra, Poddar, Brestic, Acharjee, Bhattacharya, Sengupta, Pal, Bam, Biswas, Barek, Ondrisik, and Skalicky, 2022) [13]. Prisa and Guerrini (2022) [13] using hydrogel in the germination and growth of maize (*Zea mays)* and *Solanum lycopersicum* concluded that hydrogels have many uses due to their ability to bind water. Polymers can absorb up to 600 times their weight in water and alter the water capacity of the growing medium to promote the growth of plant species under water-stress conditions. These innovations can also ensure and promote plant survival under dry conditions.

This research was carried out to unravel the effect of hydrogel on the growth and development of tomato seedlings when subjected to moisture stress conditions

Materials and Methods

The experiment was conducted at Africa University shade house using seedling trays filled with pine bark. The experiment was laid out in a complete randomised design (CRD) with a factorial arrangement. The hydrogel application and moisture stress treatments were the independent variables while the growth and development parameters of tomato seedlings were the dependent variables.

To minimise bias and ensure fair treatment distribution in a completely randomised design, random numbers were used in a specified distribution to ensure each treatment has equal chances of being chosen randomly (Mead, Curnow and Hastead, 1993) [11]. There were four (4) treatments replicated three times.

The number of replications was determined as follows

$$\#reps = 2\left(Z_{\frac{\alpha}{2}} + Z_{\beta}\right)\left(\frac{\sigma}{\delta}\right)^2$$

Where, $Z_{\frac{\alpha}{2}}$ is associated with a type 1 error

Z_{β} is associated with type 2 error

δ is the true difference to be detected

σ is obtained from previous experiments

$$= 2\,(1.96 + 0.84)\left(\frac{\sqrt{50}}{10}\right)^2 = 2.8$$

Four (4) seedling trays of 200 cells each were used. Each tray accommodated 3 treatments divided by unplanted cells in a seedling tray. Seedling trays were treated with copper oxychloride. A dibble board was used to make planting stations. Hydrogel capsules were placed as per treatment. Trays were covered and watered. 30 seeds of a determinate hybrid variety 'STAR 9011 F1 HYBRID' were planted per treatment.

One (1) two (2) and three (3) Hydrogel capsules were placed near each tomato seed (Prisa and Guerrini, 2022) [14]. Watering was done twice a week. At seven (7), 14 and 28 days, data was collected on.

The germination percentage: Calculated based on daily observation of germinated seeds up to 14 days of sowing. The number of normal seedlings from each replication was counted, and the mean germination was expressed in percentage (ISTA, 2013).

$$\text{Seed germination } \% = \frac{\text{Number of normal seedlings}}{\text{Total no. of seeds}} \times 100$$

Seedling height: stem length was taken using a measuring ruler from the base of the soil.

Root length: Obtained by cleaning the roots with running tape water and then measuring with a ruler.

The number of leaves: Physically counted from randomly selected seedlings.

Number of true leaves: Counted during termination of the experiment 28 days after seeding

Seedling height: Stem length was taken using a measuring ruler from the base of the soil.

Root length: Root length was measured from the root collar using a ruler

Seedling dry weight: Seedlings were dried in a hot air oven, maintained at 70±1 °C temperature for 24 hours. Then the seedlings were removed and allowed to cool in a desiccator for 30 minutes. The weighing was done on an electronic balance scale in milligrams (mg).

Dry weight percentage was calculated using the following formula,

$$\text{Dry weight } \% = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

Data were subjected to statistical analysis on GENSTAT using a one-way analysis of variance (ANOVA). Means were separated using LSD test at P = 0.05 level. Analysis was based on the Linear Additive Model for CRD:

Y IJ IJI μ τ ++= ε

Where, Yij is the jth observation of the ith treatment,

M is the population mean,

I τ is the treatment effect of the ith treatment, and

Is the random error. ij ε

Results and Discussion

As shown by the bar graph in figure one (1), treatment C had highest number of leaves. The polynomial trend line indicates a poor response both at treatment A and D possibly because one hydrogel capsule supplied limited moisture to the seedlings while three capsules provided too much moisture leading to stunted leaf development explaining why one (1) hydrogel capsule resulted in the same number of leaves as in treatment D. Treatments B and C shows that two (2) and three (3) hydrogel capsules have an effect on number of leaves possibly because of the availability of moisture and minimization of leaching of nutrients.

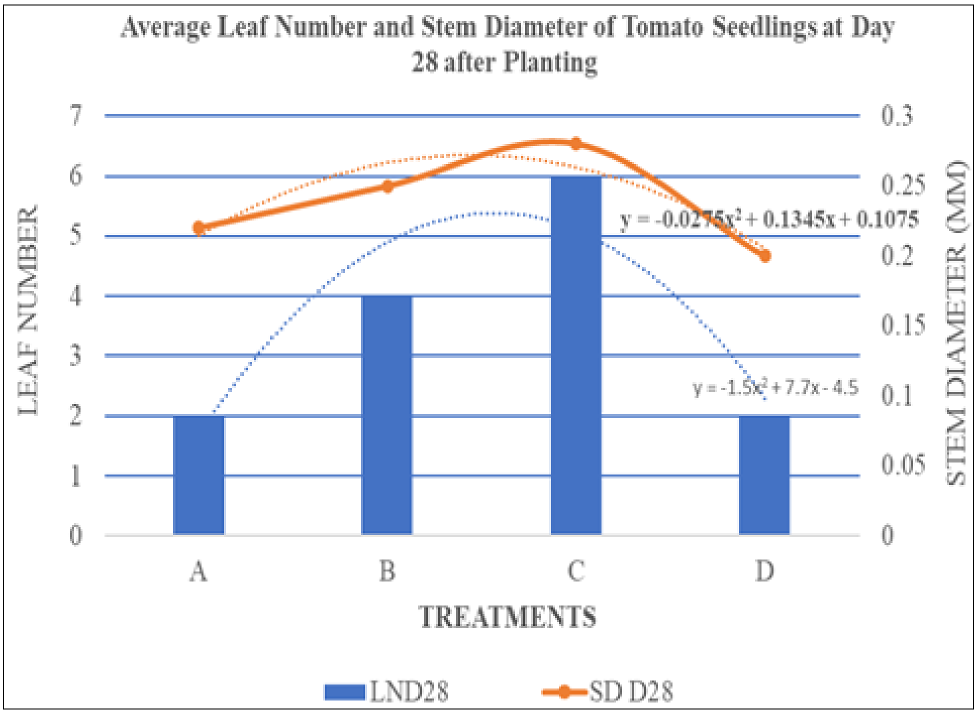

Fig 1: Effect of Hydrogel on Leaf Number and Stem Diameter.

Treatments A, B and C with hydrogel outperformed the control. Filho, Gondim, and Costa (2018) [5], reported the same trend where the application of hydrogel improved stem diameter by as much as 23%. As the polynomial trend line gets to treatment D, there is a rapid decline showing that any hydrogel rate ranging from 1-3 capsules increases stem diameter with a peak at 3 hydrogel capsules

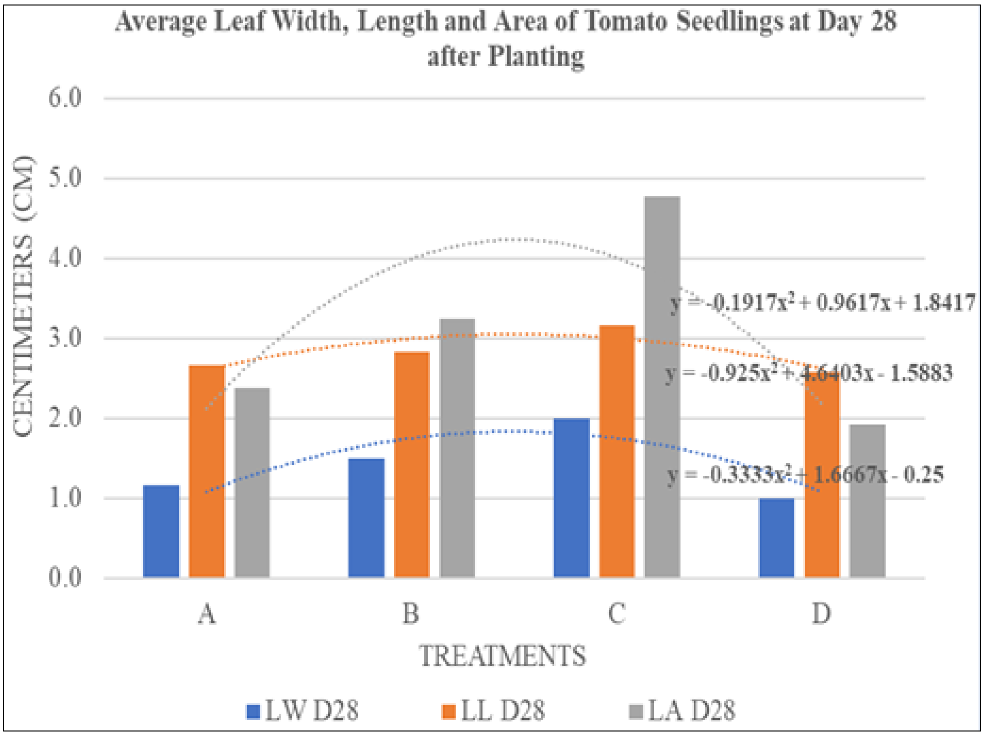

Fig 2: Effect of Utilizing Hydrogel on Leaf Width, Leaf Length and Leaf Area of Tomato Seedlings (*Solanum lycopersicum)*

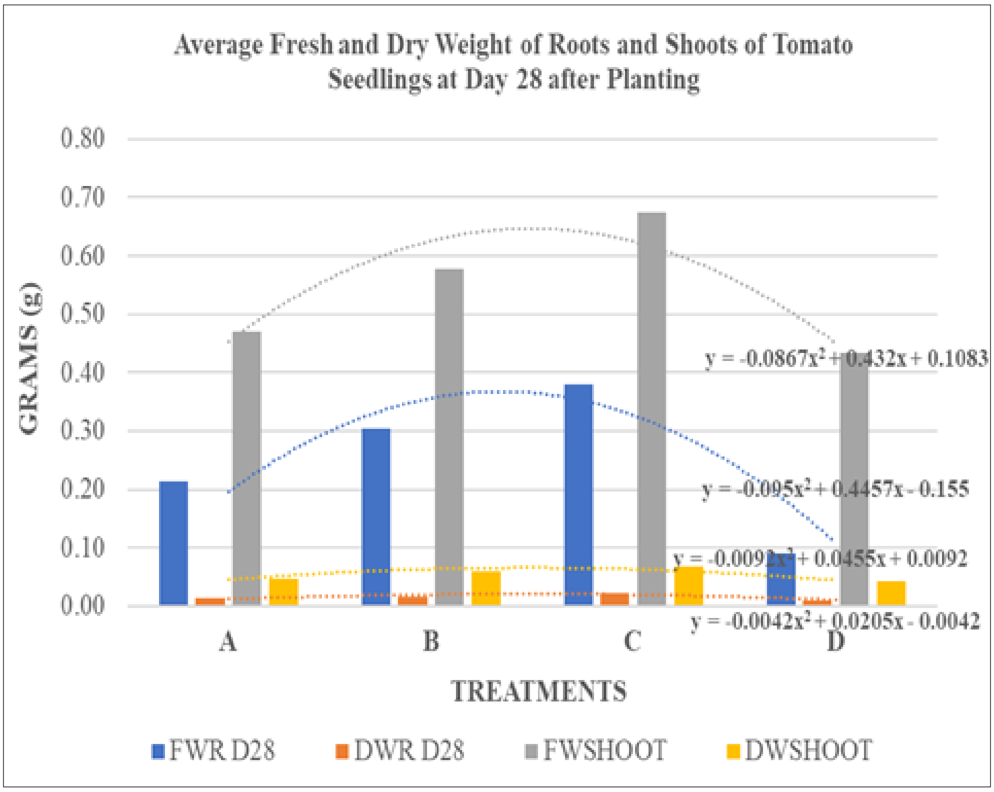

Fig 3: Effect of Utilizing Hydrogel on Fresh and Dry Weight of Shoots and Roots of Tomato Seedlings (*Solanum lycopersicum).*

The incorporation of hydrogel had a significant effects ($p \leq 0.05$) on the number of leaves, root length and fresh weight of roots.

According to Zerrouk, Sekkour, El-Gorba, & Baraket (2018) [19], Hydrogels improve plant growth under moisture stress conditions. It also increases soil water content, improves plant water status, and increases photosynthesis and antioxidant activity, all of which result in increased plant growth and development. In contrary Khalil, Tahir, Imran, Arshad, & Shahzad (2019) [8], claim that there is no significant effect posed by the use of the superabsorbent polymer (SAP).

The significant impact on the number of leaves in tomato seedlings is supported by Johnson and Woodhouse (1990) [7] who asserts the effect to be due to significant amount of water in hydrogel structure which is subsequently released into the growing media promoting leaf longevity on the plant. Negative effects of hydrogel arises because hydrogel absorbs water and fills the soil pores causing flooding in the polythene tubes that retards the growth parameters of young seedlings (Gokavi, Rudragouda, Mote, Mukharib, Manjunath, & Raghuramulu, (2018) [6], Cheruiyot, Sirmah, Ngetich, Mengich, Mburu and Kimaiyo, (2014) [3].

According to El-Hady, Rizk and El-Saify (2003) [4], hydrogels indirectly affect nutrient uptake by conservation of soil moisture and nutrient mobility helping to increase photosynthetic activity in plants enhancing vegetative growth thus improving leaves per plant and root elongation (Sharma, Jadeja, Kataria, Anamika, Dhakad (2014) [16] and (Sureshrao, Pradeeprao, Dyanobarao, Agrawal, Kotasthane (2016) [18]. The incorporation of hydrogel has been reported to increase the activity of cell division, cell expansion and cell elongation ultimately leading to an increased number of leaves, root growth and fresh weight of roots (Kumar, Chaithra, Kiran, Madhu, Nataraj, Umesha and Madhu, (2020) [9]. Similar results have been reported by Al-harbi, Al-omran, Shalaby and Choudhary, (1996) [2] in cucumber.

Incorporation of hydrogels without doubt, significant impact on tomato seedlings in relation to the number of leaves, root length and fresh weight of roots. The amount of hydrogel applied also has a positive effect on the number of leaves obtained. However, in some plants increased amounts of the superabsorbent polymer affect vegetative and root growth. Possessing knowledge on the right amount of hydrogel to apply in attaining the highest number of leaves, longest roots and fresh weight of roots per specific plant is of paramount importance as it avoids toxic side effects which may affect plant growth and development.

To attain significant effect of hydrogel on seedlings it is of paramount importance to assess the best media to use, the amount of hydrogel to apply and the crop/plant being grown.

Conclusion

Pine bark is both a low fertility growing and water retaining media. Seedlings may suffer to acquire their required nutrients and moisture content. The addition of hydrogel to the growing media playsa significant role in improving seedling growth and development. With an increase in hydrogel capsules, there was an increase in the growth parameters of the tomato seedlings which comprised of the emergence %, number of true leaves, root length, fresh weight and dry weight of seedlings, fresh weight of shoots and roots, seedling length, leaf length, leaf width and shoot diameter. Less water was applied whilst producing more as the seedlings were only watered twice the whole week as compared to having to water them almost every day. Hydrogels are mainly a water conserving technology. However, they pose many other benefits aside from conserving water which promote seedling growth and development.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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