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Original Article

Survival and Growth of Olive Tree (Olea africana) Seedlings Under Open Field Conditions is Enhanced in Hydrogel Amended Soils Media, Teso Subcounty, Kenya

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ABSTRACT

The rapid decline of timber from natural forests against increasing domestic demand for wood products has caused a steady increase in timber prices in Kenya. Recently, research and development institutions have recognized the ecological and economic value of indigenous tree species and therefore have emphasized the importance of their future production on private smallholder farms rather than in large plantations. This situation has been worsened by climate changes such as the frequent high intensity of prolonged droughts and the nature of soils with poor water retention capacity. As a result, unplanted forest regeneration sites have increased hence a need for re-afforestation of these sites to meet the target for the plantation industry. Therefore, there is a need for mass production of *Olea africana* seedlings for reforestation programs. One such approach is the application of hydrogels or synthetic polymer organic combinations capable of improving the water and nutrient retention of the soil that can support seedling growth. This study sought to investigate the effects of hydrogel application on selected growth characteristics of *O. africana*. Seeds were germinated and transferred into two sets of tubes of the same size arranged in a complete randomized block design (CRBD) experiment. The sets were subjected to different levels of hydrogel concentration. Under (0gm as control) and 7gm, 14gm, and 21gm) concentration levels of hydrogel mixed with soil in open field conditions. The height and shoot collar diameter of germinated seedlings were measured every two weeks for two months. The survival of *O. africana* seedlings decreased with time for all treatments irrespective of the addition of hydrogels with the highest (85%) survival of seedlings on soils mixed with 21gm of hydrogel compared to 0gm hydrogel that recorded (15% survival) eight weeks after

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transplanting. Application of different levels of hydrogel on soils had a significant influence on the survival of transplanted *O. africana* seedlings ($p<0.05$). Generally, the height of *O. africana* seedlings increased with time for all types of treatments (0, 7, 14 and 21gm of hydrogel); however, the rate of growth of seedlings was highest (0.667cm /week) on soils treated with 21gm of hydrogel and least (0.33cm/week) on 0gm hydrogel. The shoot collar diameter of *O. africana* seedlings increased with time for all types of treatments (0, 7, 14 and 21gm of hydrogel); however, the average shoot collar diameter of *O. africana* seedlings was highest (0.088mm/week) on soils inoculated with 21gm hydrogel and least (0.066mm/week) on soils not inoculated with hydrogel. These results imply that a higher dose of hydrogel significantly enhances the survival and growth characteristics (height and shoot collar diameter) of transplanted seedlings by improving the water-holding capacity of soil and making it available for plant uptake during dry conditions. Hydrogels can therefore be used to amend soils for a sustainable mass regeneration of tropical timber species for reforestation programs, increased forest cover and restoration of biodiversity in Kenya.

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INTRODUCTION

Climatic changes have acerbated water needs by plants in agricultural and timber production, making the development of various models for preserving soil moisture and reducing water consumption in agriculture very important (Đurović et al., 2012). Water deficit in the soil is a major challenge experienced in plantation and farm forestry establishments in many parts of the tropical and temperate regions in the world (Six et al., 2002).

Soils generally differ in moisture-holding capacity, temperature, and mineralogy (Orikiriza et al., 2013). Water-saving technologies that enhance tree seed germination, seedling growth and survival in

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soils of different properties are required. The part of grounds intended for tree nursery establishment for afforestation programs is characterized by a lack of moisture and alimentary substances. Such grounds comprise sandy soils that have low water retention capacities (Orikiriza *et al.*, 2013).

Hydrophilic polymers are used in horticulture and agriculture practices as water absorbents for better water support of plants with partial water deficiency (Rehman *et al*., 2011). Kumaran *et al*. (2010) describes hydrophilic polymers as agents with the ability to absorb 100 to 300 times their weight in water. Studies by Dubrovskii et al. (2001) acknowledged the ability of hydrophilic polymers to improve soil water retention. While Abd *et al.* (2006) singled out the benefits of polymers as a superabsorbent in the soils thus improving physical properties, aeration, seed germination and root system development in compacted soil, and water retention in lighter soils.

Different soils and tree species exhibit varying responses to super absorbent Polyacrylate (SAP) such as hydrogel amendment. Several studies have shown that the addition of hydrogels to growing media increased water holding capacity by up to 400 % (Johnson, 1994) and decreased water stress by delaying the onset of wilting (Gehring & Lewis, 1980). In water-stressed soils, for instance, prolonged survival and improved growth have been recorded under drought conditions (Apostol et al., 2009) and in sandy desert soils (Abedi-Koupai et al., 2008). SAPs were reported to increase tree species' survival and reduce evapotranspiration in different soils under drought conditions, according to Orikiriza *et al.* (2013).

Most studies on hydrogel application have been conducted on sandy soils (Bhardwaj et al., 2007) with less attention to loamy and clayey soils. Thus, the behaviour of hydrogels in the latter soils remains largely unexplored and could potentially limit their application over a wide range of agro-ecological zones

Olea africana is a shrub tree species with a height ranging from 5 to 18 m. It has a grey to brownish-blackish bark that varies from smooth to rough when old, as described by Orwa *et al.* (2009). Despite its socio-economic contribution, the species are overexploited and under threat of depletion. To upscale the population of *O. Africana*, there is a need for mass production of seedlings for afforestation (Abungu *et al.*, 2018). Based on this background, the study therefore sought to investigate the effects of hydrogel application on selected growth characteristics of *O. africana* in Teso Sub-County, Kenya.

MATERIALS AND METHODS

Study Area

This study was conducted in Amukura tree Nursery, Teso South Sub County, Busia County, Kenya. Eighty-one per cent (81%) of the land in the study area is under arable farming (Busia County development profile, 2013). Teso South Sub County lies within an altitude of between 1100 -1500 m above sea level (masl). The annual temperature ranged between 26^{o}C to 30^{o}C with an average annual rainfall of 800 to 1600 mm/year (Osumba, 2011). It has a population of 117,947 persons with a population density of 452 persons per km^2 and an average farm size of fewer than 2.1 acres (Osumba, 2011).

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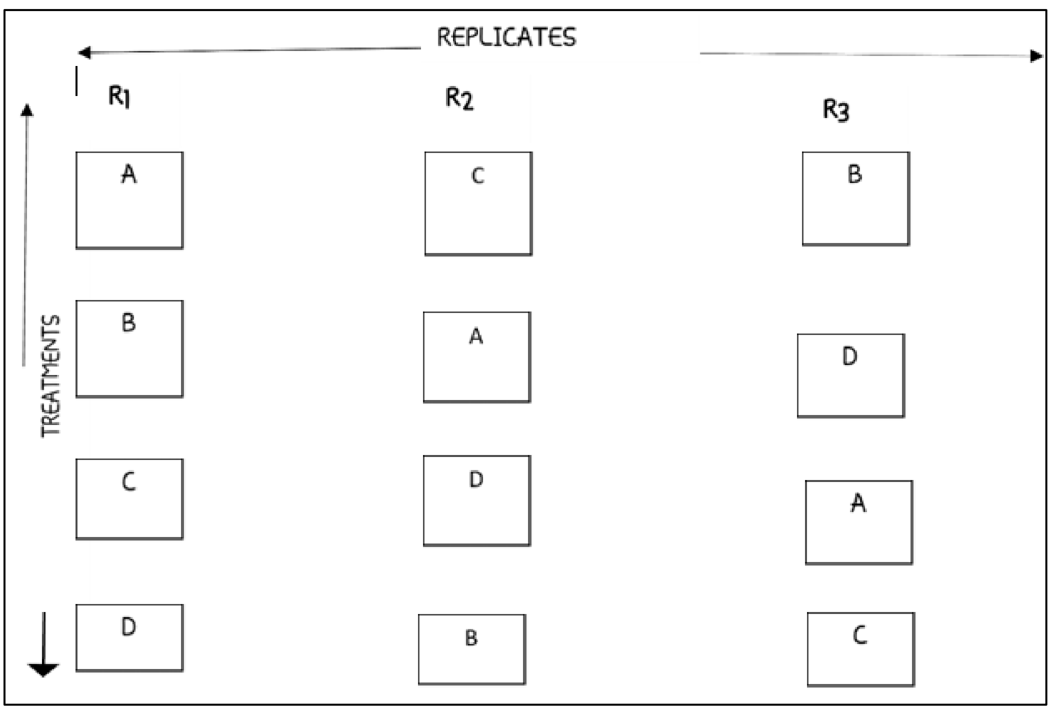
Research Design

The study adopted an experimental design. Certified *O. africana* seeds were acquired from Kenya Forestry Research Institute (KEFRI) Muguga seed centre, while hydrogel (BELSAP) was acquired from Milans Agrovet Londiani, Kenya, respectively. *O. africana* seeds were germinated in a Swaziland bed and then transplanted into potted polythene tubes measuring four by 6 inches containing 800gm sandy soil mixed with (0gm, 7gm, 14gm and 21gm) hydrogel. Each experiment was replicated three times in an open field.

Layout of the Open Field Experiment

50 *O. africana* seedlings potted in polythene tubes containing sandy soil inoculated with hydrogel concentration (0gm, 7gm, 14gm and 21gm) and in three replications were selected respectively for this study. Hydrogel treatments were randomly assigned within the blocks. Labelling of potted tubes was done according to the level of hydrogel concentration. Treatment A contained moist sand with 0gm of hydrogel (control), B with 7gm, C with 14gm and D with 21gm of hydrogel, respectively. The Complete Randomized Block Design (CRBD) was applied for the experiment, as shown in *Figure 1*.

Figure 1: Figure 1: Layout of the Open Field Experiment



Key: R-Replicates, A- Treatment (soil/0gm of hydrogel), B-soil/7gm hydrogel, C-soil/14gm hydrogel and D –soil/21gm of the hydrogel.

Survival and Growth of *O. africana* seedlings

After the first week of transplanting, survival, shoot collar diameter, and height was evaluated weekly for a period of two months and means were evaluated.

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Survival Rate of O. africana seedlings

The survival count of *O. africana* seedlings was evaluated weekly after transplanting for two months. A number of wilted, dead, and abnormally growing seedlings from each sample and treatment were counted and recorded every week up to the end of the study period.

Survival percentage (SP) was then calculated as follows:

$$SP\ (\%) = \frac{Number\ of\ health\ seedlings}{Total\ number\ of\ transplanted\ seedlings}\ x\ 100$$

Growth Rate O. africana seedlings

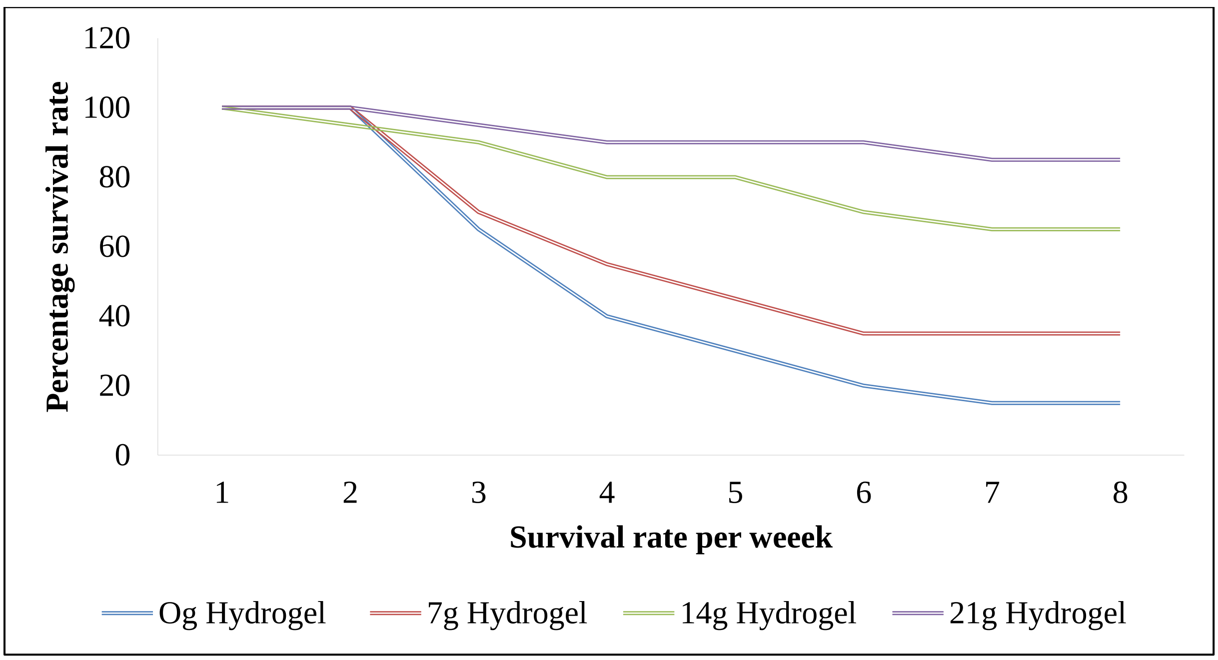
The growth rate of *O. africana* seedlings was based on height and shoot collar diameter measurements. The height (mm) was measured from the base to the highest point of each seedling and replicated. The average height (mm) was evaluated separately for each treatment. The shoot collar diameter (mm) was measured weekly for each seedling at ground level using a vernier calliper, and then the average value was taken for all treatments.

RESULTS AND DISCUSSION

Effects of Hydrogel on Survival of *O. africana* Seedlings

Figure 2. Presents results on the survival rate of transplanted *O. africana* seedlings against time in potted soil tubes with or without hydrogel.

Figure 2: % Survival of *O. africana* Seedlings Against Time



Generally, results indicate that survival of *O. africana* seedlings decreased with time for all treatments, irrespective of the addition of hydrogels. However, results showed the highest (85%) survival of seedlings on soils mixed with 21gm of hydrogel compared to 0gm hydrogel

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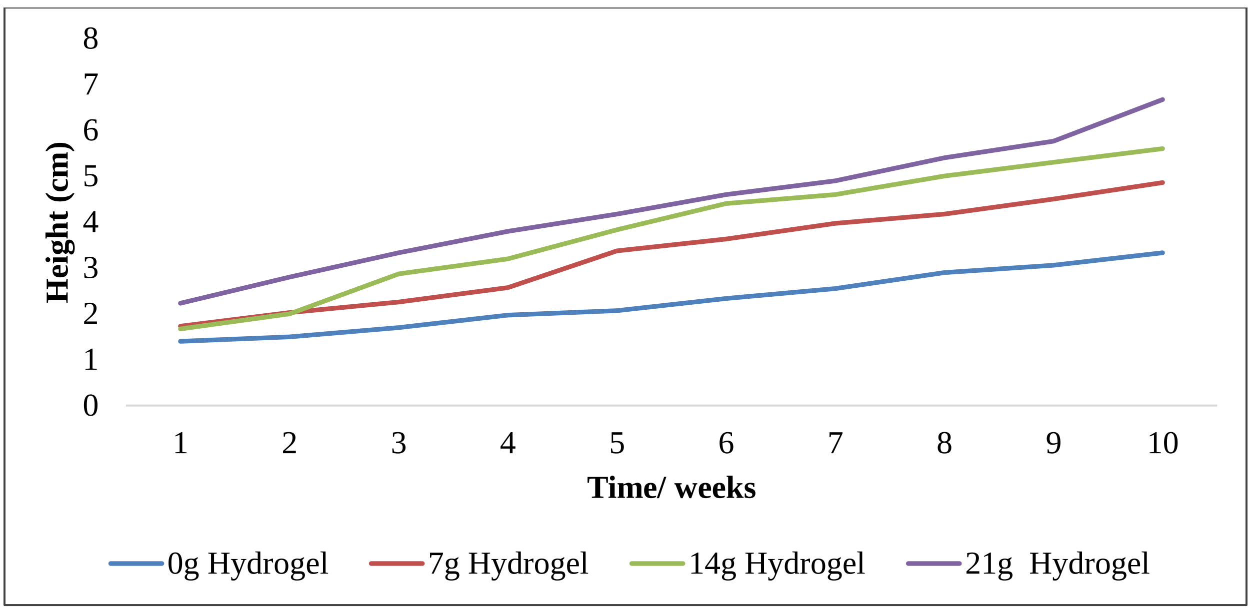
that recorded (15% survival) 8 weeks after transplanting. Application of different levels of hydrogel on soils had a significant influence on the survival of transplanted *O. africana* seedlings ($p<0.05$).

These results imply that a higher dose of hydrogel application enhances the survival of transplanted seedlings. Hydrogels improve the water-holding capacity of soil and make it available for plant uptake during drought conditions (Agaba *et al*., 2010), hence their survival. These results are further supported by Sarvaš *et al*. (2007) who observed that the application of hydrogel increased the survival rate of transplanted pine seedlings compared to the control. Hydrogel affected the survival of pine seedlings during two vegetation periods after planting. Double application of stockosorb agro (gel) on the root system after lifting caused about 19% higher survival rate compared to control variants. Observations by Montesano *et al*. (2015) indicated that hydrogel application to soils showed a positive impact on seedling survival rates and a general overall enhancement of plant growth and quality.

Effects of Hydrogel on Height of *O. africana* seedlings

Figure 3 shows the variation in mean height of seedlings exposed to 0, 7, 14 and 21gm of hydrogel within a period of 8 weeks.

Figure 3: Effects of hydrogels on Height of O. africana against Time



Generally, the height of seedlings increased with time for all treatments (0, 7, 14 and 21gm of hydrogel). The rate of growth of seedlings was highest (0.667cm /week) on soils treated with 21gm of hydrogel and lowest (0.33cm/week) on 0gm hydrogel. These results imply that a higher concentration of hydrogel enhances the change in growth height of *O. africana* seedlings. The results showed a significant difference in the height of *O. africana* seedlings within the different hydrogel levels applied $p<0.05$.

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These results indicate that the application of hydrogel polymers to the soil in areas with low rainfall is likely to boost the growth of transplanted *O. africana* seedlings. Previous studies observed that the part of grounds intended for afforestation is characterized by a lack of moisture and alimentary substances. Such grounds may include sandy soils that are poor in water and alimentary substances, dunes, post-industrial areas (sand pits, gravel pits, dumping grounds) and rotten peat as well (Boczoń et al., 2009).

Hydrogel is a good absorbent of macromolecule compound that can effectively bind water. The possibility of hydrogel retaining water is essential in the case of poor soils with low water retaining abilities, especially when seedlings are growing in unfavourable drought conditions (Boczon *et al.*, 2009). In order to improve the parameters of soil, the application of resources capable of retaining water and other alimentary ingredients in the soil is necessary. One such approach to improving the water economy of soil is the use of hydrogels or synthetic polymer organic combinations called soil conditioners (Lawrence et al., 2013).

Previous studies by Tomášková *et al.* (2020) observed a positive growth of drought-sensitive and tolerant tree species in a semi-arid region on soils treated with different levels of the hydrogel. Several studies have found that hydrogel application to the soil in areas with insufficient soil moisture content improves plant performance (Tomášková *et al.,* 2020). Konzen *et al.* (2017) found that hydrogel application in soils in areas prone to drought conditions had a positive effect on the growth of *Mimosa scabrella* seedlings and agreed with the findings by Kumar *et al.* (2018) who recorded the highest plant height among other growth parameters in treatment with the highest level of Pusa hydrogel.

Similar results were registered by Montesano *et al.* (2015) who found that the application of hydrogel to soils showed a positive impact on the development of seedling parameters (height, root collar diameter, enhancement of plant growth and quality. However, some studies have reported non-significant effects of hydrogel on plant growth according to (Vencurik *et al*., 2013) and (Cheruiyot *et al*., 2014), whereby increasing the level of hydrogel had a negative effect on the height and root collar diameter of *cajanas cajan.* It is therefore concluded that the application of hydrogel to soil media significantly influences the changes of *O africana* seedlings.

Effects of Hydrogels on Shoot Collar Diameter of *Olea africana* Seedlings

Figure 4 shows the changes in shoot collar diameter of seedlings exposed to 0, 7, 14 and 21gm of hydrogel within a period of 10 weeks

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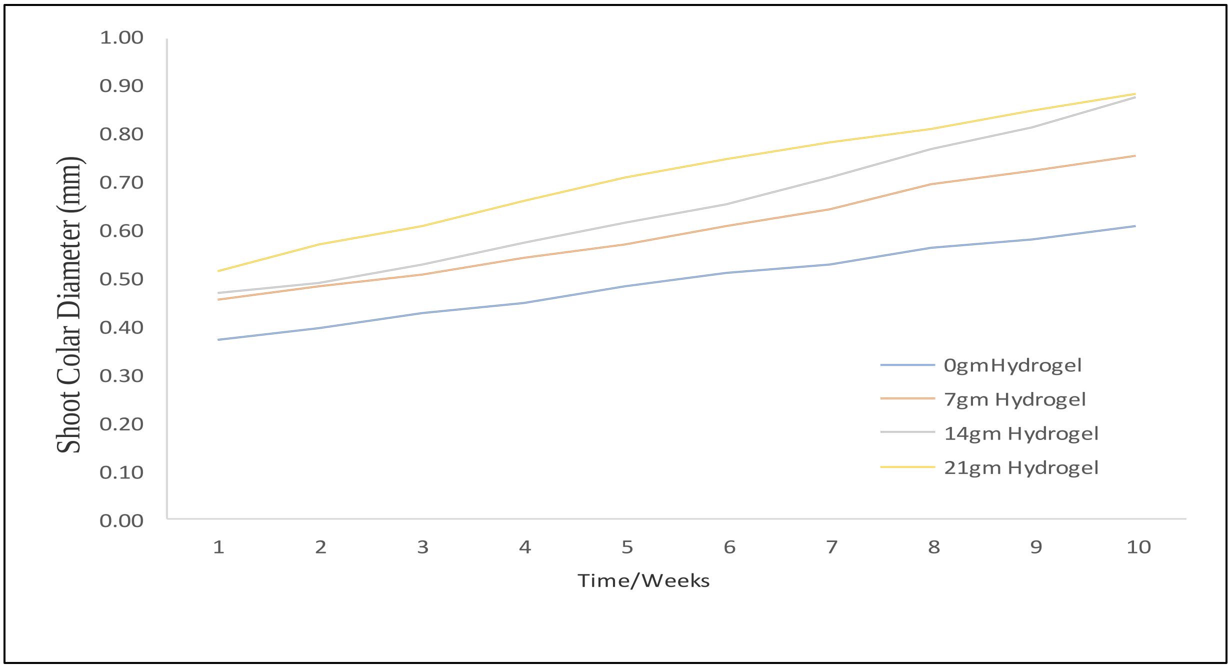
Figure 4: Changes in Shoot Collar Diameter of O. africana With Time



Generally, the shoot collar diameter of *O. africana* seedlings increased with time for all types of treatments (0, 7, 14 and 21gm of hydrogel). The average shoot collar diameter of *O. africana* seedlings was highest (0.088mm/week) on soils inoculated with 21gm hydrogel and least (0.066mm/week) on soils inoculated with 0gm hydrogel. Increasing the amount of hydrogel inoculated in soil media enhances the shoot collar diameter of seedlings, therefore, can be used to amend soils in semi-arid areas for a positive impact on the diameter growth of planted seedlings.

Studies by Kumar *et al.* (2022) found that the application of hydrogel on soil improves the growth and yield of different field crops. Mangaiyarkarasi et al. (2020) in their studies also found that different concentration levels of hydrogels had a great influence on the growth characteristics of foliages. The results from this study showed that the inclusion of hydrogels in potting media could improve the water availability and thereby improves the growth parameters of plants, especially that are grown in a pot and this can be replicated in the field for transplanted seedlings.

Hydrogels as water absorbent, exert the defined binding power of water particles and as a consequence, can cause the limitation in water collected by the seedlings in cases where the potential of soil water is greater than the power drawing of roots. The surrounding of roots because of the hydrogel can act as a restrictive factor for the occurrence of mycorrhizas. The symbiosis between trees and fungi is a basic condition for the correct water economy of forest trees (Lawrence *et al.*, 2013).

CONCLUSIONS

The height of *O. africana* seedlings increased with time for all types of hydrogel treatments (0, 7, 14 and 21gm of hydrogel). The rate of growth of seedlings was highest (0.667cm

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/week) on soils treated with 21gm of hydrogel and lowest (0.33cm/week) on 0gm hydrogel. These results suggest that the higher the concentration of hydrogel application, the higher the reported growth of seedlings. It is therefore concluded that the application of hydrogel to soil media significantly influences the changes in the height of *O. africana* seedlings. The average shoot collar diameter of *O. africana* seedlings was highest (0.088mm/week) on soils inoculated with 21gm hydrogel and least (0.066mm/week) on soils inoculated with 0gm hydrogel. Increasing the amount of hydrogel inoculated in soil media enhances the shoot collar diameter of seedlings therefore can be used to amend soils in semi-arid areas for a positive impact on the diameter growth of planted seedlings.

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