Effects of Hydrogels on Soil Moisture, Nutrient Availability and Growth of *Sesbania sesban* and *Cajanus cajan* in Semi Arid Zone of Kongelai, West Pokot County

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Abstract

Studies on the effects of hydrogels on soil amendments, moisture conservation, nutrients release and growth of Sesbania sesban and Cajanus cajan in arid and semi-arid lands was carried out. Seedlings of S. sesban and C. cajan were established both in the nursery and in the field with and without hydrogels. Field experiment was carried out under hedgerow intercropping system with three replications and three concentration hydrogels levels (7g, 11g and 15g). In the nursery, root collar diameter (RCD) and heights for each seedling were measured every two weeks up to eight weeks. Seedlings established without hydrogels in the nursery were transplanted into field soils with none, 7g, 11g and 15g of hydrogels. Root collar diameter and height were again measured every month for three months. In addition, soil was collected randomly once every month from the base of each seedling and analyzed for soil moisture and nutrient content. All data were subjected to analysis of variance. Results showed that there was a significant difference in the height and RCD among the three species and at different level of hydrogels. This suggests that use of hydrogels in the nursery soils retards plant growth but improves growth in the field. Hydrogels increased soil moisture content transplanting. Analysis of variance of nutrients release into the soil shows that hydrogels has an effect on the nutrients. Nutrient increased from 0.95, 0.07 and 0.12% in the pre-test analysis to 4.48, 3.81 and 0.42% after analysis in potassium, nitrogen and phosphorus respectively in the soil after transplanting. It was concluded that hydrogels do not contribute to growth of seedlings in the nursery but it does so after transplanting. Hydrogels increase soil moisture and nutrients in the soil therefore recommended for use in semi arid lands to boost the survival and growth of seedlings.

Keywords: *Hydrogels, Moisture, Nutrients, Growth, Semi-arid*

Introduction

Kenya is a developing country striving to achieve vision 2030 (Muchiri *et al*., 2009). One way of achieving such goals is to improve the livelihood of people living in arid and semi arid lands through introduction of appropriate agroforestry technologies and practices to mitigate aridity (Okorie, 2003). The forest cover in Kenya is currently standing at 1.7% way far below the internationally accepted minimum of 10% (IPCC, 2008); therefore, a need to support the development of forestry practices to increase forest cover towards the required minimum percentage. On the basis of moisture availability for plant growth, Kenya is classified as 88% arid and semi-arid with a population over of 10 million many of whom are pastoralists and agro-pastoralists (GoK, 2010a).

Agroforestry, a sustainable land use system and optimal production of any agroforestry practice, is influenced by the combination of tree and agricultural crops, amount of soil nutrients, moisture conditions and rate of organic matter decomposition (Bruno *et al*., 2013). Similarly moisture retention in the soil is fundamental in the growth of agroforestry tree species. Soil water affects plant growth directly because it influences aeration, temperature, nutrient transport, uptake and transformation (Zhongkui *et al*., 2011).

Hydrogels are networks of polymer chains that are hydrophilic and highly absorbent to water molecules (Abedi-Koupai, 2008). The addition of hydrogels to soil can improve not only its water holding capacity, but also the supply of plant available nutrients. Hydrogels usually have some effects on plant establishment, with the greatest benefit for hydrophilic plants planted in drier conditions where the lack of water availability could be attributed to the amounts of soluble salts in the medium (Sabine *et al*., 2013).

The study, therefore, aims at investigating the effects of hydrogels on soil water availability and nutrient release by monitoring the growth of *Sesbania sesban* and *Cajanus cajan* seedlings in the nursery and their early establishment in the arid and semi arid lands of Kongelai.

Materials and Methods

Location and Climate of Study Area

The study was carried out in Kongelai, West Pokot County (Latitude: 1.47^{0}71'S; Longitude: 35.02^{0}07'E). The study area lies between 1500 to 2100 metres above sea level, characterized by bimodal type of rainfall with the long rains between April to August and short rains between October and February. The study area was characterized by great variations in temperature with 30 °C in the lowlands and 15 °C the highlands.

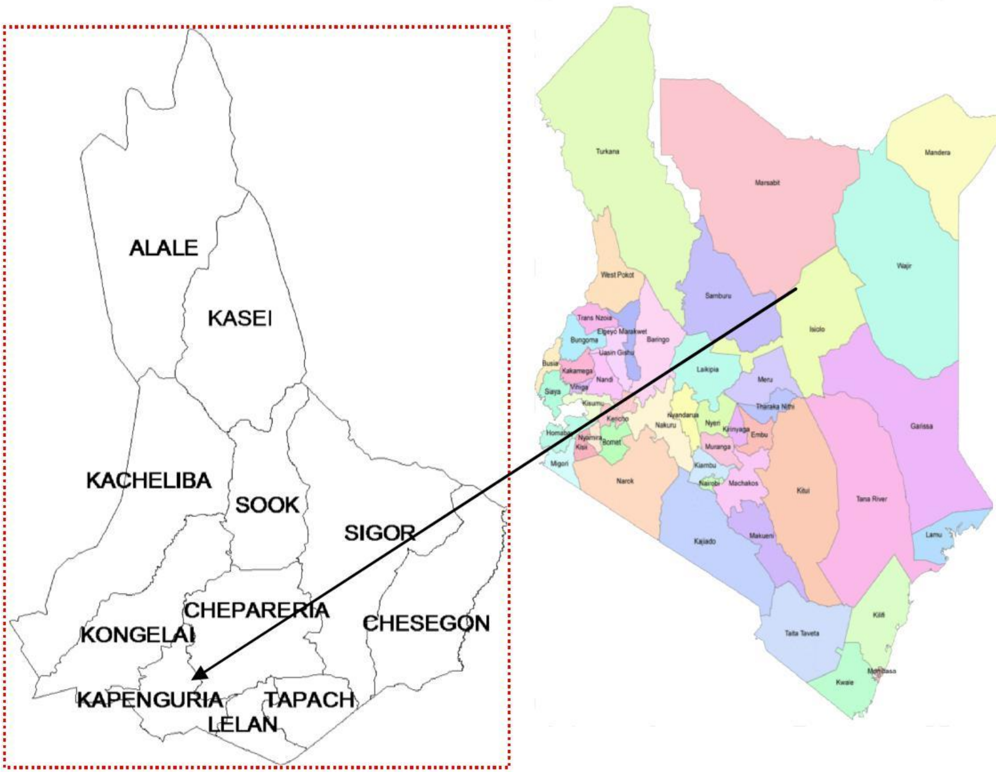

Figure 1. Map of study area, West Pokot County
Source: County Commissioner's Office, 2013

Two agroforestry species, namely *Sesbania sesban* and *Cajanus cajan*, were used in the study. The hydrogels used was called *Belsap* manufactured by Bell Industries limited. Potting soil was obtained from Kapolet Forest Station

Procedures in the Nursery

Seeds of *Sesbania sesban* and *Cajanus cajan* were directly sown into polythene tubes measuring 4 x 6 inches containing 800g of forest soil and at different levels with hydrogels others without hydrogels. A total of 2 treatments were prepared for each species. Each treatment consisted of 42 seedlings of the respective tree species at 0, 7, 11 and 15g hydrogels levels replicated thrice. Treatments were randomized within the blocks. All polythene tubes were labelled for identification purposes. Once germinated, root collar diameter and height were measured every two weeks for two months. Randomized block design arranged in a split plot design was used in this experiment. The main plots were the tree species: *S. sesban* and *C. cajan* while the sub-plots were a control and three levels of hydrogels: H_0, H_{7}, H_{11} and H_{15g}.

Procedures in the Field

After two months, control seedlings in the nursery were de-potted and transplanted into pre-tested soil samples in a field within the same region. All seedlings treated with hydrogels in the nursery were not transplanted. In the field, the same levels as in the nursery were applied in the planting holes mixed with soil. Thirty seedlings were used for each tree species replicated thrice. Once a month for two months, RCD and height of seedlings were measured. In addition soil samples were collected from the base of each growing seedling for moisture and nutrients released analysis. With the exception of hedgerows in the field, experimental design remained as in the nursery.

Determination of Soil Moisture

Fifty grams of soil from 0-10cm horizons was collected in the field using a soil auger under *S. sesban* and *C.s cajan* seedlings. Initial weight was determined and the sample oven dried at 100 °C. Oven dry weight was determined and soil moisture content determined.

Soil Analysis

Soil analysis was done in the laboratory for nitrogen, phosphorus and potassium using Okalebo *et al.*'s (2002) method. The data collected was analyzed using Microsoft Excel; Analysis Toolpak, a computer package for data analysis. F-Test was used to test the level of significance.

Results and Discussion

Effects of Hydrogels on Height of Seedlings in the Nursery

The height of *Sesbania sesban* seedlings was measured at an interval of 2 weeks in the nursery as shown in Figure 2 below.

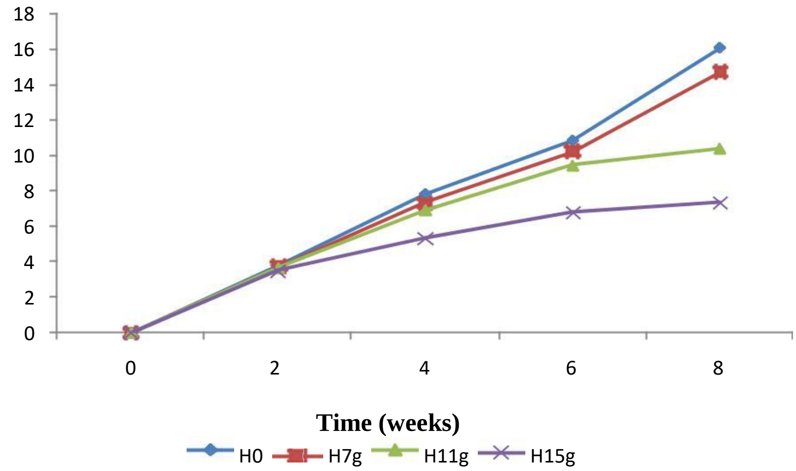

Figure 2. Effects of hydrogels on height of *Sesbania sesban* seedlings in the nursery

Sesbania sesban established in soils with no hydrogels gave higher height growth than those in soils treated with hydrogels. Soils treated with the higher amount of hydrogels (H15g) gave the least growth in height of seedlings. Analysis of variance for the height of *Sesbania sesban* shows that $F_{0.05}$ (1) [15, 3] = 10.3431 > F critical (3.4903). This implies that hydrogels application has a significant difference on the height growth. Similar trend of height growth was observed in *Cajanus cajan* {$F_{0.05}$ (1) [15, 3] = 3.6182 > F critical (3.4903)} established under the similar conditions as shown in Figure 3.

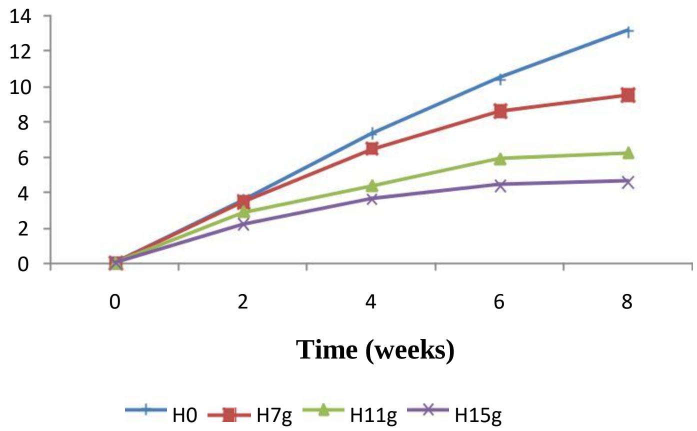

Figure 3. Effects of hydrogels on height of cajanus cajan seedlings in the nursery

Effects of Hydrogels on Root Collar Diameter of Seedlings in the Nursery

The RCD of *Sesbania sesban* seedlings was measured at an interval of 2 weeks in the nursery as shown in Figure 4 below.

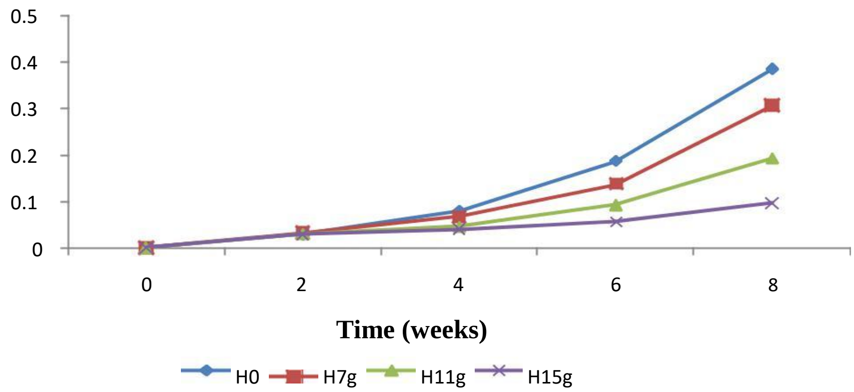

Figure 4. Effects of hydrogels on RCD of sesbania sesban seedlings in the nursery

Sesbania sesban seedlings established in soils with no hydrogels gave higher RCD growth as compared to seedlings established in soils treated with hydrogels. Analysis of variance shows that $F_{0.05}$ (1) [15, 3] = 7.5909 > F critical (3.4903). This implies that hydrogels application has a significant difference on the root collar diameter growth.

Similar trend of RCD were observed in *Cajanus cajan* {$F_{0.05}$ (1) [15, 3] = 6.9127 > F critical (6.2913)} treated with similar levels of hydrogels as shown in figure 5.

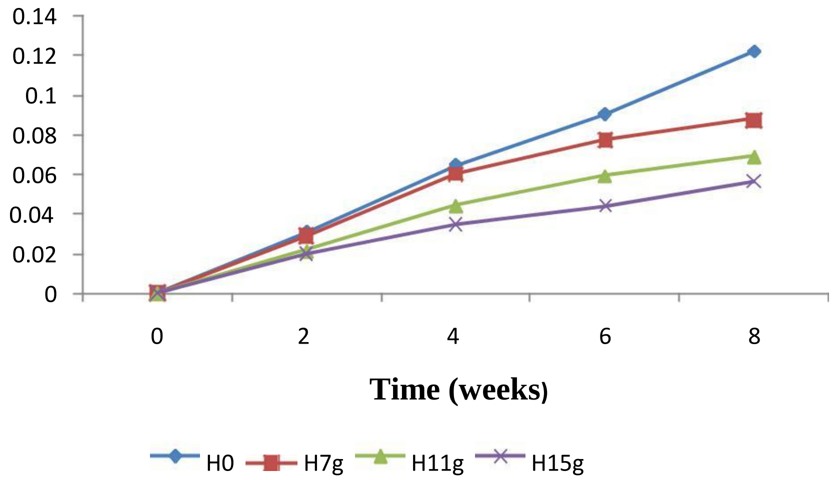

Figure 5. Effects of hydrogels on RCD of cajanus cajan seedlings in the nursery

Increasing levels of hydrogels has a negative effect on the growth of seedlings in the nursery both in RCD and height. Hydrogels also absorbs water and fills the soil pores causing flooding in the polythene tubes therefore retards the growth of seedlings. This findings was in total agreement with what other researchers (Antonio *et al.*, 2011; Audun, 2012) have reported that hydrogels contribute to the scorching effect on the early growth of seedlings and flooding in the polythene tubes in the nursery.

Effects of Hydrogels on Height of Seedlings in the Field

S. sesban seedlings grown in soils with no hydrogels gained least growth in height than those in soils treated with hydrogels. Analysis of variance for the height of *S. sesban* shows that $F_{0.05}$ (1) [15, 3] = 3.4903 > F critical (0.0508). This shows that hydrogels has a significant difference on the growth of transplanted seedlings hence use of hydrogels in the soil in the field has a positive impact on height growth.

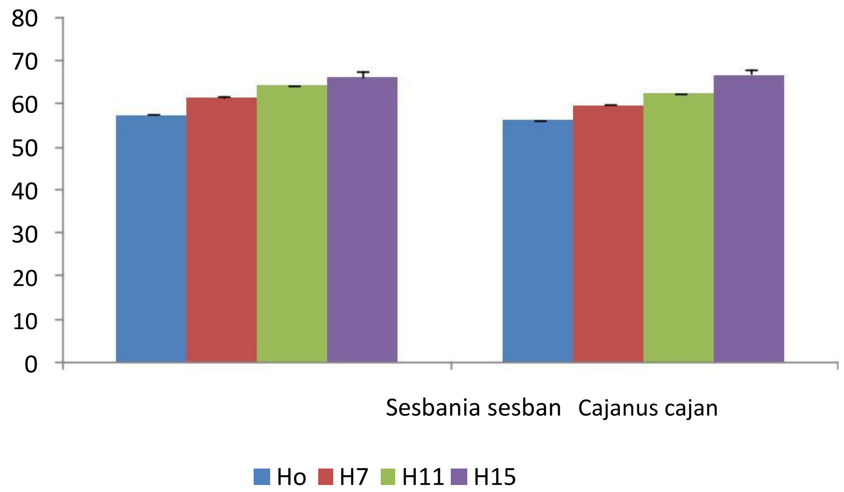

Figure 6. Effects of hydrogels on height of transplanted seedlings after 3 months

Similar trend of height increase was observed in *C. cajan* {$F_{0.05}$ (1) [15, 3] = 144.8962 > F critical (3.4903)} under the same conditions in the field.

Effects of Hydrogels on RCD after Transplanting

Sesbania sesban seedlings grown in soils with no hydrogels gained least RCD growth as compared to seedlings treated with hydrogels. Analysis of variance shows that F $_{0.05}$ (1) [15, 3] = 7.9651 > F critical (3.4903) implying that hydrogels has a significant difference on the RCD growth.

Similar trend of RCD were observed in *C. cajan* {$F_{0.05}$ (1) [15, 3] = 138.89 > F critical (3.4903) treated with similar levels of hydrogels.

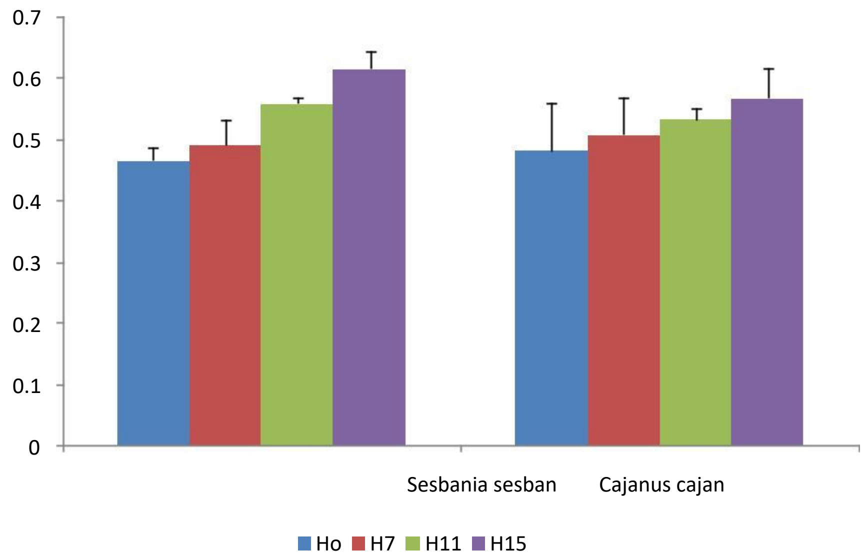

Figure 7. Effects of hydrogels on the RCD of transplanted seedlings at 3 months

Hydrogels is used in arid and semiarid areas to improve the growth of agroforestry tree species. Michael *et al.* (2010) reports that hydrogels absorbs water which can improve the growth of seedlings after transplanting in arid environment. Their results of the study confirm that changes in the nutrient status of the soil were influenced by the application of hydrogels which resulted to the increase in soil fertility hence the differences in growth rate.

Starkey *et al.* (2012) and Raja *et al*. (2013) have ascertained that gels has been used to establish tree seedlings and transplants in the arid regions of Africa to increase plant survival therefore higher height growth and RCD of seedlings was result in an increase in hydrogels as compared to controls. This concurs with the findings in this paper in the semi arid region.

Effects of Hydrogels on Soil Moisture

Soil moisture content was determined in the subplots under the three species and the results were as presented in the figure below.

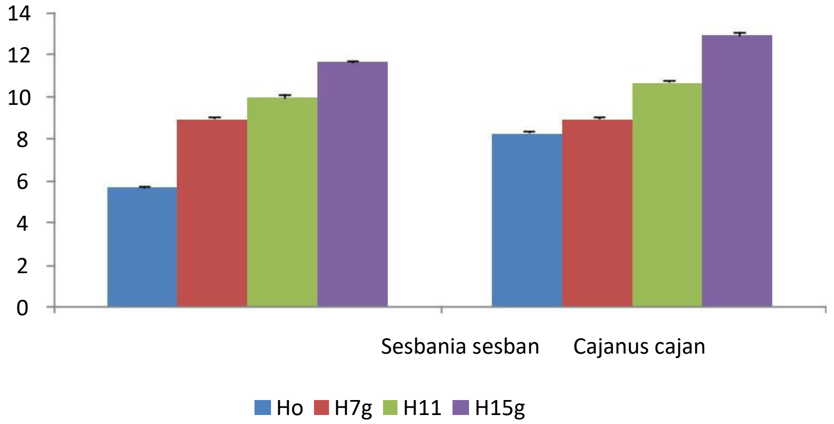

Figure 8. Effects of hydrogels on soil moisture after transplanting

Hydrogels had an impact on soil moisture content in the soil after transplanting in arid and semi arid climate. Analysis of variance shows that; $F_{0.05}$ (1) [11, 3] = 5.2690 > F critical (4.0662) implying that hydrogels has a significant difference on the growth of transplanted seedlings in the field.

Kimondo (2000), Akhter (2004) and Landis (2012) have reported that hydrogels improve soil moisture content in the soil and provide water to the plants during dry season. This was experienced in soils treated with hydrogels, which gained more soil moisture content compared to controls as shown in Figure 8 above. Mousavinia (2006), Karimi *et al.* (2008) and Raja *et al.* (2013) aver that using hydrogels helps to improve water holding capacity in the soil and thus provide plants with moisture during dry period thereby hastening the growth in arid and semi arid lands. Sohrab (2004) and Bhat *et al*. (2009) in another experiment evaluated water holding capacity by hydrogels in three kinds of soil and concluded that application of hydrogels increased amount of available moisture to the plant by 1.5 times than their controls. Their findings concur with results that were found in this experiment.

Soil Nutrient Analysis

In the laboratory N, P and K were analyzed in each treatment in the laboratory. The nutrients content are as shown in Figure 9 below.

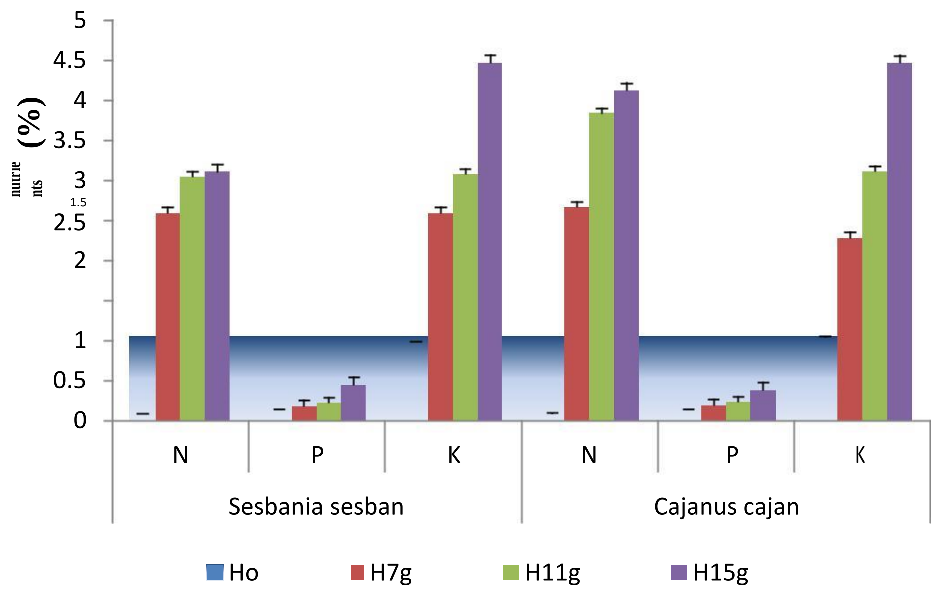

Figure 9. Nutrients release into the soil by agroforestry tree species after transplanting

Major nutrients, i.e. N, P & K, were analyzed since seedlings requires for early growth. Analysis of variance for nutrients release into the soil shows that $F_{0.05}$ (1) [35, 3] = 5.4270 > F critical (2.9011). This implies that application of hydrogels in the soil has a significant different on the growth of transplanted seedlings therefore increasing soil nutrients release into the soil. Hydrogels improves soil nutrients when planted together with agroforestry tree species.

Akhter *el al.* (2004) and Antonio *et al.* (2011) have ascertained that hydrogels application improves nutrients in the soil plant nutrition in arid and semiarid lands but they didn't give percentages at a particular level of hydrogels.

Kimondo (2000), Moftar and Humaid (2007), Abedi-Koupai (2010) and Mark *et al.* (2012) also comment that hydrogels when used in arid and semi arid lands will increase not only moisture content but also improve nutrients to the plants. Their conclusion was in agreement with these findings.

Antonio *et al.* (2011) found out that application of hydrogels in the soil during transplanting can improve the potassium in higher percentage than other major nutrients required by the plant during early growth. They reported that severe drought conditions according to seedling size and nutritional status, with special emphasis on potassium.

Conclusion

Hydrogels has negative impacts in height and root collar diameter growth of seedlings in the nursery but it has positive impacts after transplanting.

Hydrogels when incorporated into growing media or soil absorbs moisture in the environment and retain water therefore it is used in arid and semi arid areas to increase plants survival after transplanting.

Hydrogels supply the plant with major nutrients (N, P & K) apart from moisture content. When applied as a root dip, hydrogels can release nutrients into the soil.

Recommendations

Hydrogels was recommended not to be used in the nursery unless when there is water scarcity but should be used in transplanted seedlings under moisture stress environment. Further studies to be done to compare hydrogels effects on a range of soil types using a wide range of tree species.

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