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Assessing the Impact of Hydrogels on Early Growth of Maize Grown in Sandy Regosols

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ABSTRACT

World food production has been challenged by prolong drought conditions associated with changing climate in the world. Super Absorbent Polymers or hydrogels gained immense interest in recent days due to their water-holding properties in soil, enhancement of soil porousness, reduction of irrigation requirement and enhance plant growth. This study was conducted to evaluate the impact of four different hydrogels produced together with one commercially available hydrogel on early growth of maize in sandy soil with low soil water holding capacity. The early growth of hybrid Maize variety Paccific 984 was tested with six treatments. T1 (Hydrogel type A-reference gel), T2 (Hydrogel type B- urea incorporated), T3 (Hydrogel type C-without urea), T4 (Hydrogel type D urea incorporated), T5 (commercial hydrogel) and T6 (Control-no application of hydrogel). The experiment was designed in a Randomized Complete Block Design. Plant growth parameters including plant height, number of leaves and total dry matter production were recorded. Soil properties were determined at the beginning and at the end of the experiment. Results showed that plants treated with locally produced hydrogels have been given the highest growth performance than control and commercial product treatments. T2 has been recorded with highest plant height (128.90 cm), leaf area (1153.3 cm^2) and total dry mass production (49.36 g) while T4 has recorded with highest stem girth (4.87 cm). There was a significant difference among soil pH, total N% and available P among treatments. T2 showed the highest total N% (0.19) while T4 showed the highest P concentration (18.94 ppm). The results revealed that locally produced hydrogels have given superior performance over commercial hydrogel in enhancing plant growth. It can be concluded that locally produced hydrogels formulation used in T2 and T4 can effectively be used in enhancing growth of maize while minimizing the risk than using imported commercial hydrogels.

KEYWORDS: Soil fertility, Super absorbent polymers, Water holding capacity, Water scarcity

INTRODUCTION

With the fast decline of irrigation water potential and continued expansion of population and economic activity in most of the countries, the problem of water scarcity is expected to be aggravated. Furthermore, the food production is increasingly challenged by various abiotic stresses including prolong drought conditions in the world with recent climate change.

In Sri Lanka, drought is looming into a larger issue as one-third of the population is engaged in agriculture-related activities. Therefore, in Sri Lanka agriculture has been severely affected by changing climate. Soil water retention is a major soil hydraulic property that governs soil functioning in ecosystems and greatly affects soil management for crop production (Rawls *et al.*, 2003). Plants need water and nutrients throughout their life cycle and all aspects of plant development are affected by a reduction in water content in the soil. This reduction in soil moisture leads to changes in the physical environment, which subsequently affect physiological and biochemical processes in plants. Plants respond to moisture stress by reduced height, reduced leaf size, a lesser number of leaves, less fruit production and changes in the reproductive phase. Finally, the total crop production will be decreased.

Plant available water in soil depends on the soil properties. Water scarcity is the most limiting factor for plant production in arid regions. In arid and semi-arid regions, soils often have unfavorable soil physical properties. In coarse sandy soils, it is impossible to store sufficient water in a plant-available form during irrigation (Banedjschafie and Durner, 2015). Therefore, the farmers who have sandy soils, have to irrigate frequently to obtain optimum production.

Kalpitiya in Sri Lanka belongs to dry zone, receiving an average annual rainfall of 1067 mm. Sandy Regosol is the major soil type in this area. Farmers in Kalpitiya struggles with the issues related less water retention ability in these sandy soils.

Sandy soils have a light texture and loose structure since the particles are large and surrounded by air pockets, which provides plenty of open spaces for water to move through. Therefore, the water does not pool on the surface and drain quickly. As a result, frequent irrigation and nutrient loss has become a severe problem for farmers having sandy soils. Therefore, improving water retention is considered to be very beneficial.

Incorporating organic matter in to the soil is considered as a solution to create a better structure in order to increase the water holding capacity in sandy soils. However, its applicability is challenged due to unavailability of organic matter in these areas. Besides technical developments to achieve more efficient irrigation, the application of Super Absorbing Polymers (SAPs) commonly known as hydrogels have become a measure to improve plant production by enhancing ability to retain moisture (Banedjschafie and Durner, 2015).

Superabsorbent polymers (SAPs) or hydrogels are a unique group of materials that can absorb over a hundred times of their weight in liquids and do not easily release the absorbed fluids under pressure. They can be applied to increase water retention in sandy soils. The addition of Super Absorbent Polymers to a sandy soil changes the water holding capacity to a comparable position. It has found that adding Super Absorbent Polymers to the soil matrix increased the water availability for plant use (Yazdani *et al*., 2007). Polymers consists of molecules having high molar masses and consist of a large number of repeating units. Polymers are formed by chemical reactions containing monomers which are joined sequentially, forming a chain. (Nori and Reddy, 2014). The most important characteristics of these polymers are their ability to absorb and keep the surrounding area damp and not wet. This is done by forming a gel with the polymer (Nori and Reddy, 2014). Commonly consuming polymers in agriculture are polyacrylamide, polyacrylacid, etc. It has been proven that unit gram of hydrogel can retain 400-1500 gram of water. (Woodhouse and Johnson, 1991).

There are many benefits of using Super Absorbent Polymers for sandy soils where water retention is lowest. Hydrogels can nullify the bad effects of drought conditions by increasing the soil water holding capacity. Furthermore, previous test results have shown that evaporation losses from soils get reduced (Banedjschafie and Durner, 2015). The most significant feature is that they can absorb water up to hundreds to thousands times than their weight and release it at a slow pace which keeps the plants hydrated for a long time. It also minimizes the leaching impacts on soil. Moreover, the hydrogels act like a perfect soil matter flocculent. They help in binding loose soil by forming loams. These loams create a space for aeration and are helpful in better root latching. Eventually, the over compaction of soil minerals gets prevented. As well these SAPs are biodegradable since it degrades naturally (Nnadi and Brave, 2011).

In the world, there are many Super Absorbent Polymers which are already used in agricultural sector. However, the outcome results and side effects of these hydrogels cannot be assured with regarding to the local environment. For an instance, sometimes these commercially used, imported hydrogels may include pathogens or harmful materials to the local environment. Therefore, it is important if these materials can be produced locally that suits for our local environment, excluding potential risks.

Therefore, this study was carried out with the objective of evaluating the effectiveness of locally produced hydrogels to enhance water holding capacity and plant growth in sandy soils. The impact of different hydrogel types was assessed using early growth of maize grown under rain-fed conditions.

MATERIALS AND METHODS

Location

Experiment was carried out at a net house in the Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila situated in Low Country Intermediate Zone at elevation of 30 m from mean sea level. The laboratory analysis was carried out in the Soil Science laboratory of Department of Plantation Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila (NWP) from July to November 2019.

Experimental Design

The experiment was conducted in Randomized Complete Block Design with six treatments within three blocks. Spacing of 60 cm was maintained between two pots as well as between each block. The treatments are given in Table 1.

Treatment Application

Growing media was prepared in plastic pots by using sandy soil which were collected from Kalpitiya area in Sri Lanka. Four grams and six grams from each treatment were applied to pots before and three weeks after planting respectively.

Table 1. Treatments of the experiment

Treatment	Composition
T1	Hydrogel type A The reference gel
T2	Hydrogel type B Urea incorporated
T3	Hydrogel type C without Urea
T4	Hydrogel type D Urea incorporated
T5	A Commercial gel
T6	Control

Crop Establishment and Maintenance

For germination, Pacific 984 Hybrid variety seeds were soaked in distilled water for three days. They were sown (two seeds per pot) two days after the application of basal dressing. One month after planting the top dressing was applied according to the recommendation of the Department of Agriculture, Sri Lanka. Manual weeding, pest and disease control practices and other cultural practices were done according to the recommendations providing similar conditions for all treatments.

Vegetative Parameters

Plant height, Plant girth, number of leaves, leaf area, total dry matter production were measured. Plant height was measured in each plant in treatment using a measuring tape from base of the plant to the last fully open leaf at two weeks intervals up to 11th week from planting. Plant girth was recorded at the heights of 45 cm from base of the plant. Number of leaves were counted per each replicate at two weeks intervals. Leaf area was measured at the end of the experiment. Then samples were dried at 80°C to a constant weight in order to calculate total biomass production.

Soil Sampling and Sample Preparation

Soil samples were collected from three points of the pot away from the roots at the depth of 10 – 15 cm of each pot one month and three months after planting. These samples were air dried at room temperature and sieved by 2 mm sieve and stored for chemical analysis. For initial analysis, a composite, representative sample was prepared by mixing.

Soil Chemical Analysis

Soil pH was measured by using a glass electrode/pH meter. Electrical Conductivity was determined using conductivity meter and cell.

Walkley and Black method was used to determine Soil Organic Carbon as cited in Dharmakeerthi *et al*. (2007).

Total Nitrogen in soil was determined by using Kjeldahl method as cited in Dharmakeerthi *et al*. (2007).

Olsen method was used to quantify the available Phosphorus in soil as cited in Dharmakeerthi *et al*. (2007) and the absorbance was measured at 880nm wave length using Spectrophotometer (SHIMADZU model UVmini-1240).

Hydrometer method was used to determine the soil texture as cited in Dharmakeerthi *et al*. (2007).

Statistical Analysis

Analysis of variance was used to analyze the data using SAS Statistical software (version 9.4).

RESULTS AND DISCUSSION

Vegetative Parameters

Plant Height

Mean values of plant height are given in Table 2. Plant height is correlated generally with life span, seed mass and time to maturity, and is a major determinant of a species' ability to compete for light. The differences in plant height were significant. T2 and T4 gave higher values while control treatment (T6) showed the lowest plant height during experimental period. Furthermore, T1, T2, T3 and T4 were significantly different with T5 (commercial hydrogel) with respect to mean values of plant height.

Table 2. Mean values of plant height

Treatment	Hydrogel Type	Mean Plant Height (cm)
T1	A	110.77^{abc}
T2	B	128.90^{a}
T3	C	103.70^{bc}
T4	D	124.97^{ab}
T5	Commercial	91.93^{cd}
T6	-	79.57^{d}
P<0.05		0.0022

T6- Control-no application of hydrogel, Means with different letters within the same column represent significant differences at P=0.05 level

Plant Girth

The mean values for plant girth recorded during week 9 to week 11 were shown in Table 3. In week 10, T2 was significantly different with T1 and T6. Differences among plant girth was significant in week 9. T6 showed the least girth value than all other treatments. T4 and T2 showed the highest girth values. This may be due to the provision of N with hydrogel that enhance plant growth.

Table 3. Mean values of plant girth (cm)

Treatment	Week 9	Week 10	Week 11
T1	3.77[bc]	2.97[a]	3.40[a]
T2	4.57[ab]	4.83[a]	4.67[a]
T3	4.37[abc]	3.70[ab]	3.00[a]
T4	4.87[a]	4.23[ab]	4.10[a]
T5	3.40[cd]	3.40[ab]	3.50[a]
T6	2.70[d]	2.97[b]	3.30[a]
P<0.05	0.008	0.0692	0.2491

Means with different letters within the same column represent significant differences at P=0.05 level

Number of Leaves

Mean values of number of leaves per treatment and leaf area are given in Table 4. There was no significant difference between treatments. Control showed the lowest number than other treatments. This may be due to the improvement of growing condition in soil of treatments other than control. T3 treatment gave higher values for number of leaves compared to all other treatments.

Table 4. Number of leaves and leaf area per treatment (cm^2)

Treatment	Number of leaves	Leaf area (cm^2)
T1	16.33[ab]	699.7[b]
T2	15.67[ab]	1153.3[a]
T3	16.83[a]	775.5[b]
T4	16.33[a]	1018.3[a]
T5	15.67[ab]	444.7[c]
T6	15.33[b]	444.8.7[c]
P<0.05	0.1691	0.0005

Means with different letters within the same column represent significant differences at P<0.05 level.

Leaf Area

The highest mean value (Table 4) for the leaf area was recorded with T2 and T4 while the lowest recorded was from T6. Ultimately T2 and T4 treatments showed higher performance in plant growth. There is a significant difference between T2 and T1. T1 and T3 showed relatively lower leaf area compared with T2 and T4 and higher leaf area than T5 and T6.

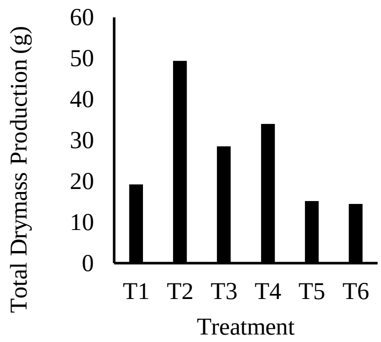

Figure 1. Total dry mass content per treatment.

T2 and T4 treatments showed a significant difference with others. The highest mean value of the total biomass production was observed with T2 (49.36 g). The dry matter content in T2 and T4 were significantly higher than others. T6 showed the lowest mean value. Control treatment may have suffered lack of nutrients. However, irrespective of supply of same level of nutrients commercial hydrogel has given lower growth compared to other treatments supplied with hydrogels.

Initial Soil Parameters

Soil samples which were taken from planting medium before applications of treatments were analyzed and mean values were recorded (Table 5).

Table 5. Chemical parameters of soil used for planting media

Parameter	Mean ± SD
pH	7.19 ± 0.08
EC (µS/cm)	134.30 ± 2.17
OC %	0.30 ± 0.16
Total N %	0.04 ± 0.02
Available P (ppm)	39.41 ± 4.60

Soil pH of planting media was 7.19 and which is in neutral range and suitable for the growth of maize. According to the results, organic carbon level and total nitrogen of initial soil was very low. However, available P in this soil was very high (Dharmakeerthi *et al*., 2007).

Analysis of Soil Properties after Treatment Application

Soil samples which were taken one month after application of treatments analyzed for chemical properties (Table 6).

Table 6. Chemical parameters of soils of different treatments after application

Treatment	pH	EC (µS/cm)	Total N %	Available P (ppm)
T1	7.23^{c}	68.63^{b}	0.09^{bc}	16.52^{ab}
T2	7.27^{c}	71.60^{ab}	0.19^{a}	13.46^{bcd}
T3	7.40^{b}	75.33^{a}	0.12^{ab}	11.78^{cd}
T4	7.49^{ab}	75.93^{a}	0.12^{ab}	18.94^{a}
T5	7.45^{ab}	69.73^{ab}	0.01^{c}	15.22^{bc}
T6	7.53^{a}	72.93^{ab}	0.04^{bc}	11.02^{d}
P<0.05	0.0019	0.2353	0.0268	0.0055

Means with different letters within the same column represent significant differences at P=0.05 level.

Soil pH was ranged from 7.23 to 7.53 among treatments and showed a significant difference among treatments. The highest pH was indicated by control (7.53) while the lowest was recorded by T1(7.230). All treatments showed an increment in soil pH with compared to initial status. However, soil pH was in neutral range.

Soil Electrical Conductivity (EC) was varied between 68.63 (µS/cm) to 75.93 (µS/cm) and the maximum EC was given by T4 while the minimum was given by T1. There was no significant difference in EC among treatments.

Total soil N was ranged from 0.01% to 0.19% (Table 6). T2 showed the highest N content than others. However, T2, T3 and T4 showed a significant improvement in total N content than initial status. It indicates that the locally produced hydrogels tested could enhance the soil N content over the growing season.

Soil available Phosphorous was varied from 11.02 ppm to 18.94 ppm (Table 6). There was a significant difference among treatments and T4 (18.94 ppm) showed the highest P content than other treatments.

CONCLUSIONS

Results indicate that application of hydrogels has enhanced the growth performance of maize. According to the results, locally produced hydrogels have given superior performances over commercial hydrogels with relevant to enhancing plant growth. It can be concluded that locally produced hydrogel formulations in T2 and T4 can effectively be used in enhancing growth of maize while minimizing the risk than imported commercial hydrogels.

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