
Research Article

Bio-organic approach for monitoring the plant growth for sustainable agriculture

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Abstract

Agriculture plays a critical role in sustaining life and driving the economy of India. The idea of sustainable agriculture is a holistic approach to meet the demands of food supply while protecting our environment. Through various sources, it has been found out that the country is running out of the main reservoirs of water to irrigate the fields. The present study investigated the possibility to prepare different natural hydrogels using Chia seeds, Flax seed, Gond katira, Arrowroot powder, Tapioca, Agar-agar, Corn starch, Gelatin, *Aloe vera*, and their comparison with a synthetic hydrogel used in sanitary napkins. On successful formation of natural hydrogels and getting valuable results in their water holding capacity, the work continued to test their potential on growth and development of seeds of two plants: Moong beans (*Vigna radiata*) and Fenugreek (*Trigonella* sp.) along with bio-organic fertilizers prepared from onion, garlic and banana respectively. Seeds were sown in soil less media (Coco-coir) and the study of various parameters like phytotoxicity test, seed germination, water consumption, number of leaves, root and shoot length indicated promising results in the establishment and healthy growth of the seedlings. Use of natural biodegradable hydrogels therefore may prove as an easy, low cost and eco-friendly way to establish the seedling development and subsequent productivity at the commercial level under conditions of water scarcity for sustainable agriculture.

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1. Introduction

Agriculture plays a critical role in sustaining life and driving the economy of a country. By incorporating the idea of sustainability to agriculture, our aim is to meet the demand of adequate food supply for the ever-growing population without compromising our environment. This can be achieved by limited or no use of synthetic fertilizers, pesticides and insecticides along with the proper use of water for irrigation (Abobatta, 2018). Through various studies conducted to analyse the resources used for irrigation in India and the impact of increasing water shortage on agriculture, it has been found out that groundwater is the main aquifer which is depleting at a much higher rate than it can be replenished. The country is running out of the main reservoirs due to lack of rainfall and according to the precipitation patterns, the rainfall lasts for only 3-4 months mainly in summers, thus making the winter harvesting difficult which accounts for 44% crops of the country (Jain et al., 2021). Also, the water consumption for agriculture purpose is 90% of the total groundwater consumed annually, sources of which are 70% contaminated (McCarthy, 2021).

Over the last 40 years, the agriculture sector has been focusing on enhancing water availability for crops by bettering the water holding capacities of the soil for increased productivity with the help of hydrogels (Montesano et al., 2015).

Hydrogels are cross-linked polymers in a three-dimensional network, which have the capability to absorb & hold large quantities of water or biological fluids due to their hydrophilic nature (Chai et al., 2017; Nascimento et al., 2018). They can show two types of cross-linking: Chemical and Physical. The chemical crosslinking involves the formation of covalent bonds by chemical reactions among polymer chains. The physical crosslinking involves the formation of hydrogen bonds or interactions such as Van der Waal forces (Ahmad et al., 2019). The presence of hydrophilic functional groups like -NHR, -COOR, -OR, -CONHR, -CONR and -SO₃R helps in combining water molecules and form the chain networks. Certain physical stimuli like temperature, light intensity, pressure, electric and magnetic fields and chemical stimuli like pH and solvent composition can cause sol-gel phase transitions in hydrogels. As these transitions are of reversible nature in most cases, it allows these substances to swell and shrink according to their surrounding conditions (Bahram et al., 2016). Even after exhibiting high absorption rates (upto 400-1500 times their original dry weight in the liquid), hydrogels retain their well-defined structures (Das et al., 2019).

Broadly hydrogels can be classified into synthetic polymer hydrogels and natural polymer hydrogels, based on their extraction, chemical composition and processing. Natural hydrogels are derived from polysaccharides such as cellulose, hemicellulose, starch, alginate, chitosan and proteins such as collagen etc. Synthetic hydrogels are derived from man-made polymers like sodium polyacrylate, polyethylene glycol, polyvinyl alcohol etc (Chirani et al., 2015).

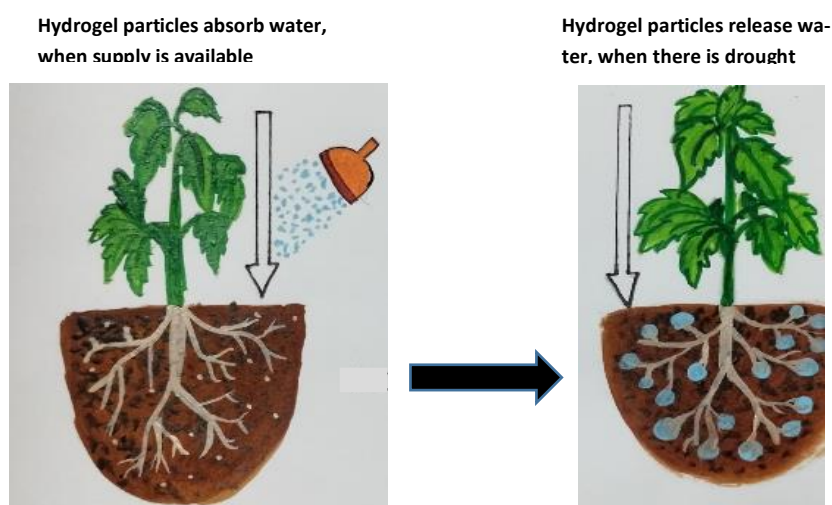


Figure 1. Use of Hydrogel in the agriculture field for plant water assimilation (Kabir et al., 2018)

The high absorptive capacity of hydrogels and various physicochemical properties that enhance their sensitivity towards pH, pressure, solvent composition & temperature, forms the basis for their increased scientific interest specifically in the biomedical field. Their potential is already being extensively researched and implemented in diverse fields including tissue engineering, drug delivery, wound management and dressing materials, water purification, nano fibres, gum metal/metal oxide nano particles and for various personal care products (Ahmad et al., 2019). The use of hydrogels in agriculture has proven to be extremely beneficial in the areas where there is lack of supplementary irrigation, steep or sloppy terrain that usually faces the problem of water run-off and soil erosion, and also areas having monsoon fluctuations or long dry periods (as shown in Figure 1) (Lather, 2018).

Both synthetic and natural hydrogels are capable of retaining water in a good capacity and in preventing minerals and nutrients from leaching. However, majority of the pre-existing hydrogels being used for agricultural practices are acrylate based, hence making them non-biodegradable with possible toxicity and lack of reaction control (Montesano et al., 2015). Lather (2018) states that many commercially used synthetic hydrogels such as PUSA hydrogel are found to precipitate into liquid when in contact with gypsum. As gypsum is present as a constituent of soil in most areas of the world and majorly in sandy soil, therefore, the use of synthetic hydrogels would be ill-suited for agricultural purposes (Lather, 2018).

Natural hydrogels, being biocompatible and eco-friendly, would not only assist in attaining our goals of sustainable agriculture, but could also serve as nutrients for the plants on decomposition (Klein & Poverenov, 2020; Abdel-Rouf et al., 2018). Their commercial application can prove to be potent for coping up with agricultural issues like drought stress, uncertain and inadequate rainfall, irrigation water wastage and decreased soil fertility (Kalhapure et al., 2016).

In the present study we have made an attempt to prepare different natural hydrogels using simple method and test their potential in agriculture. The seeds of two plants: Moong beans (*Vigna radiata*) and Fenugreek (*Trigonella sp.*) were sown in soil less media amended with different hydrogels in different ratios as well as with different bio-organic fertilizers from onion, garlic and banana respectively. Both the plants are annual dicots belonging to family *Fabaceae*, suitable for short term crop rotations and a favourable hot and warm climate (Sheteawi & Tawfik, 2007; Acharya et al., 2006). A comparative study of swelling capacity of different natural hydrogels was done followed by analysis of the growth rate of plants for a duration of 10 days on the basis of various parameters like water consumption, percent seed germination, Phyto toxicity test, number of leaves, shoot length and root length.

2. Materials and methods

2.1 Materials required

All the materials were procured in Delhi, India. Tapioca (*Manihot esculenta*), Corn starch, Flax seeds (*Linum usitatissimum*), Gond katira (*Tragacanth*), Chia seeds (*Salvia hispanica*), Arrowroot powder (*Maranta arundinacea*), Sanitary napkins, Gelatin (FRESCO'S Nature Garden) were purchased for preparation of hydrogels. Agar-agar (Thomas Baker) was procured from the Botany laboratory of Maitreyi College, New Delhi, India. *Aloe vera* plant was taken from home garden. Moong beans (*Vigna radiata*) and Fenugreek seeds (*Trigonella sp.*) were purchased from a departmental store for plant growth studies. Coco-Coir was procured from nursery. Onion (*Allium cepa*), Banana (*Musa sp.*) and Garlic powder (*Allium sativum*) were prepared from their respective sun-dried peels.

2.2 Methodology

Preparation of hydrogels

The gel structures were obtained by swelling of hydrogels in pure water with a dry gel: liquid phase (warm water) ratio equal to 3g: 100mL with stirring and whisking and then air dried for 24

hrs (Smagin et al., 2019). All studies were performed for 10 days in Maiteryi College, University of Delhi, New Delhi, India

In case of cross-linked hydrogels: (i) *Aloe vera* and Corn starch: – Equal amount of Corn starch and fresh *Aloe vera* extract were dissolved in 100mL of warm water followed by air drying for 24 hrs. (ii) Gelatin and Agar-Agar – 2g of Gelatin powder dissolved in 50mL of cold water. Mixed with 1g of dissolved Agar-agar in 50mL of warm water. Gel was formed after stirring the mixture for 30 minutes and air dried for 24 hours. Powdered Chia seeds, Flax seeds and dry gel from Sanitary napkins were used directly.

Preparation of bio-Organic fertilizers

Peels of Onion, Garlic and Banana were collected and sun dried. The dried peels were ground to a fine powder and stored in air tight containers.

2.3 Experimental setup

Moong beans and Fenugreek seeds were washed with water and soaked overnight and then planted in setups. The Control set (C1) contained 10g of Coco-coir (soil-less growing medium) and other experimental sets contained Coco-coir and hydrogels in the ratio of 1:1 and 1:2. C1: Control supplied with Coco-coir, C2: Control with hydrogel (1:1), C3: Control with hydrogel (1:2), C4, C5, C6: Control with hydrogel (1:1) and biofertilizers (Onion, Garlic and Banana). Each setup was prepared by first layering Coco-coir, a layer of hydrogel followed by a layer of hydrogel mixed with bio-organic fertilizer as per respective setups from 1 to 6. Imbibed seeds were then placed in each setup at equal distance to monitor their germination and to study various parameters. The plants were observed every day for the requirement of water. Water was added as per the requirement and the amount of water added in each setup was recorded.

25 plants after seedling thinning were allowed to grow in each setup. The plants were observed for 10 days. Three replicates were used for shoot length and root length.

2.4 Study of effect of natural and synthetic hydrogels on plant growth

Swelling capacity

Initially 2g of dry gel (W_a) was added in 40mL of water and kept for 18 hours at room temperature. The gel was then weighed after decanting the excess water (W_s). The formula used for the calculation of swelling capacity (%) for each gel is (Chaudhary et al., 2020; Hosseinzadeh & Sadeghi, 2021):

$$\text{Swelling capacity (\%)} = (W_s - W_a) / W_a \times 100 \quad \text{Eqn.1}$$

Phytotoxicity test

The Germination Index (G_{index}) for 2 plants was calculated using the given formula: -

$$G_{\text{index}} = \left(\frac{G}{G_o} - \frac{L}{L_o} \right) \times 100 \quad \text{Eqn.2}$$

Here, G and G_o are the number of seeds germinated in plants with Hydrogel and control respectively L and L_o are the root length of plants with Hydrogel and control respectively (Montesano et al., 2015).

Water consumption in different hydrogels

The water requirement for each experimental set was checked regularly and the amount of water given to each setup was measured and recorded.

Seed germination (%)

Number of seeds germinated in each setup were counted after every 24 hours upto 4 days and seed germination (%) was calculated using the formula given below: (Al-Ansari & Ksiksi, 2016)

$$\text{Seed germination (\%)} = \frac{\text{No.of seeds germinated}}{\text{Total no.of seeds}} \times 100 \quad \text{Eqn.3}$$

Shoot length

Shoot length was measured by taking the average height of three plants from each setup after every 48 hours up to 10 days by using a thread as a reference, which was further measured by a scale in centimetres and recorded.

Number of leaves

Average of the total number of leaves grown in each experimental set for every gel was recorded.

Root Length

Root length was measured 10 days after germination. Randomly three roots were taken out and measured in centimetres using a scale. Then the average of these three roots were taken as a root length for each experimental set.

3. Result and discussion

3.1 Swelling capacity of hydrogels

Hydrogels were prepared by greener method and the outcome of swelling capacity (%) of different hydrogels is shown in Table 1. The order of swelling capacity (%) after 18 hours is found to be Sanitary napkins > Flax seed > Chia seeds = *Aloe vera* + *Corn starch* > *Gond katira* > *Arrowroot* = *Tapioca* > *Agar-agar* > *Gelatin* & *Agar-agar*. The higher swelling capacity (%) of Sanitary napkins (whisper brand) is due to the presence of polyethylene along with super absorbent substance and the lowest swelling capacity (%) of Agar-agar and Gelatin – Agar-agar hydrogels is due to smooth and porous structure of Agar-agar (Mateen et al., 2012). Higher amylose content in Tapioca and Arrowroot powder is responsible for their lower swelling capacity (%) (Ariahu et al., 2011; Hodge & Osman, 1976; Jyothi et al., 2009).

Table 1. Swelling capacity (%) of different hydrogels

Hydrogel	Swelling capacity (%)
Chia seeds	300.00
Flax seed	500.00
Gond katira	200.00
Arrowroot powder	100.00
Tapioca	100.00
Agar-agar	50.00
<i>Aloe vera</i> and corn starch	300.00
Gelatin + agar-agar	50.00
Sanitary napkins	1350.00

3.2 Effect of different hydrogels on plant growth (Phytotoxicity Test i.e. G_{index})

Germination index (G_{index}) of different hydrogels using Moong beans is shown in Table 2. On an average, the G_{index} of different natural and synthetic hydrogel prepared except in the case of Tapioca hydrogel (G_{index} = 58%), was well above 60% which indicates that these hydrogels are not phytotoxic (Montesano et al., 2015). *Aloe vera* + *Corn starch* hydrogel showed very high G_{index} = 770. The higher G_{index} for moong beans (G_{index} = 770) and fenugreek seed (G_{index} = 233) in the presence of *Aloe vera* + *Corn starch* hydrogel leads to more development of root and seed germination (%) than the control. So, in the absence of phytotoxicity of different hydrogel we can use them as growing media component and they are absolutely safe for our plants (Montesano et al., 2015).

The germination index was observed to be in the following order: *Aloe vera* +Corn starch>Gond katira>Chia seeds>Arrowroot > Gelatin +Agar-agar.

Table 2. Germination index of different hydrogels using moong bean

Hydrogel	Germination index
Chia seeds	141.23
Flax seed	69.50
Gond katira	243.20
Arrowroot powder	137.23
Tapioca	58.33
Agar-agar	128.57
<i>Aloe vera</i> and corn starch	770.00
Gelatin + agar-agar	133.12
Sanitary napkins	77.71

3.3 Water consumption of hydrogels

We have recorded water consumed (mL) for Moong bean in different hydrogels (1:1 and 1:2) and control. Comparison for the same is depicted in Figure 2. It has been found out that water consumed in Coco- coir has reduced in the presence of different hydrogels (1:1 and 1:2) but *Aloe vera* – Corn starch (1:1) hydrogel has shown promising result as this system has consumed 1.7 times less water than control. Hydrogels are holding water for longer period of time due to existence of hydrophilic groups like -OH, -CONH and -NH₂. These hydrogels can be employed as a significant water - holding material in horticulture and agricultural applications (Johnson, 1984; Chen & Chen, 2019).

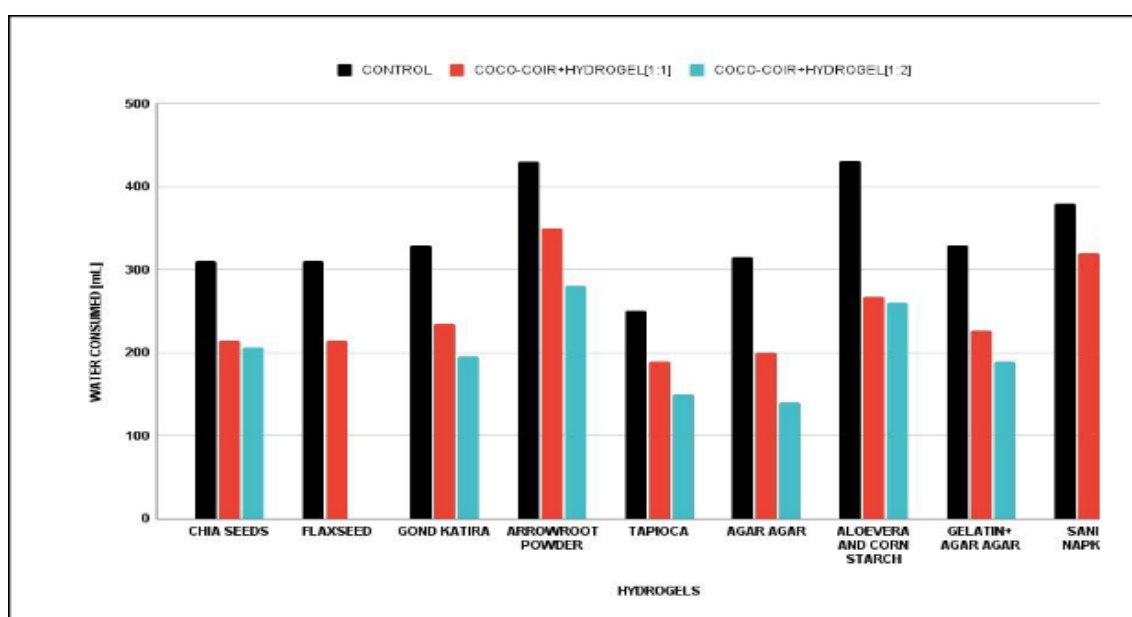


Figure 2. Water consumption in different Hydrogels in Moong Bean Plant after 10 days

3.4 Seed germination

The percentage seed germination of Mung bean was found to show significant increase in presence of Arrowroot powder, Chia seed, Gelatin + Agar-agar, *Aloe vera* + Corn starch, Agar -agar, Gond katira based hydrogels as compared to control. Tapioca hydrogel showed increased seed

germination in presence of 1:2 ratio of Coco-coir and hydrogel (Table 3). The highest seed germination percentage was observed in Arrowroot powder and lowest in Flax seed-based hydrogel.

Table 3. Seed germination (%) of moong bean in control and different hydrogels after 4 days

	Control	Coco-coir+ hydrogel (1:1)	Coco-coir+ hydrogel (1:2)
Chia seeds	74.00	82.00	80.00
Flax seed	88.00	80.00	52.00
Gond katira	26.00	60.00	64.00
Arrowroot powder	84.00	100.00	100.00
Tapioca	44.00	28.00	80.00
Agar-agar	46.67	63.44	70.00
<i>Aloe vera</i> and corn starch	26.60	73.30	80.00
Gelatin+ agar-agar	72.00	80.00	70.00
Sanitary napkin	84.00	64.00	84.00

Addition of onion peel powder bio-organic fertilizer in hydrogel was found to be effective in case of Flax seeds and Gond katira based hydrogel. Similarly, addition of garlic peel powder bio-organic fertilizer resulted in increased percentage seed germination in Flax seed, Tapioca, Agar-agar and *Aloe vera* +Corn starch hydrogels (Table 4).

Table 4. Seed germination (%) of moong beans in coco-coir+hydrogel (1:1) using biofertilizers after 4 days

	Coco-coir+ hydrogel (1:1)	Coco-coir+hydrogel (1:1)		
		Onion	Garlic	Banana
Chia seeds	82.00	32.00	76.00	20.00
Flax seed	80.00	96.00	88.00	80.00
Gond katira	60.00	68.00	40.00	36.00
Arrowroot powder	100.00	72.00	32.00	40.00
Tapioca	28.00	20.00	72.00	4.00
Agar-agar	63.44	60.00	73.34	66.67
<i>Aloe vera</i> and corn starch	73.30	26.66	83.00	43.00
Gelatin+ agar-agar	80.00	36.00	60.00	18.00

The seed germination (%) of Fenugreek plants in presence of *Aloe-vera* +corn starch-based hydrogel (1:1) was observed to be comparable to control plants. The bio-organic fertilizer of garlic peel powder was found to be effective in improving the seed germination (%) as compared to control plants (Table 5)

Table 5. Seed germination (%) of fenugreek in aloe vera and corn starch based hydrogel

Days	2	3	4	5	6
Control	–	46.66	83.00	93.00	93.00
Coco-coir + hydrogel (1:1)	–	70.00	83.00	90.00	90.00
Onion	–	57.00	80.00	93.00	93.00
Garlic	–	77.00	97.00	97.00	97.00
Banana	–	70.00	90.00	90.00	90.00

3.5 Shoot length

The Shoot length of Moong bean plant in different hydrogels was compared with control, it was found that there was significantly increase in Gond katira (11.3 cm), Agar-agar (7.1 cm), Chia

seeds (6.23 cm), *Aloe vera* + Corn starch (3.7 cm), Gelatin + Agar-agar (5.75 cm) based hydrogels when taken in 1:1 ratio with Coco-coir (Table 6). The maximum shoot length was observed in Arrowroot powder (12.98 cm) and the minimum shoot length in *Aloe vera* + Corn starch (3.7 cm). The increase in shoot length showed similar results when the Coco-coir and hydrogel were taken in 1:2 ratio. It was observed that shoot length was found to be increased in Arrowroot powder (15.88 cm), Gond katira (12.8 cm), Agar-agar (5.7 cm), *Aloe vera* + Corn starch (4 cm) based hydrogels as compared to control.

Table 6. Shoot length (cm) of moong bean plants in control and different hydrogels after 10 days

	Control	Coco-coir+ hydrogel (1:1)	Coco-coir+ Hydrogel (1:2)
Chia seeds	5.10±3.39	6.23±2.48	5.15±1.55
Flax seed	7.06±0.12	3.90±0.79	No growth
Gond katira	6.80±0.76	11.30±1.61	12.80±0.58
Arrowroot powder	16.02±1.87	12.98±1.46	15.88±1.57
Tapioca	13.90±0.10	8.00±3.00	12.00±1.00
Agar-agar	3.20±0.20	7.10±0.17	5.70±0.06
<i>Aloe vera</i> and corn starch	1.20±0.30	3.70±0.44	4.00±0.20
Gelatin+ agar-agar	4.39±2.45	5.75±2.79	4.50±1.25
Sanitary napkin	12.90±2.88	11.81±1.63	12.05±0.67

The shoot length in presence of all three bio-organic fertilizers showed very significant and promising results as compared to control in Gond katira and Agar-agar based hydrogels. Garlic powder proved an effective bio-organic fertilizer when added to hydrogels of Tapioca (14 cm) and *Aloe vera* + Corn starch (10.2 cm), Gelatin + Agar-agar (6.58 cm) (Table 7). The maximum shoot length was observed in Tapioca (14 cm) and the minimum shoot length in Flax seeds (2.25 cm) hydrogels.

Therefore, our study indicates that some of the hydrogels used resulted in improved shoot length. The seed germination and seedling stage depends on availability of water. The hydrogel helps in providing sufficient moisture content thereby facilitating improved germination and establishment of seedlings.

Table 7. Shoot length (cm) of moong bean in coco-coir+hydrogel (1:1) using bio-organic fertilizers after 10 days

	Coco-coir+ Hydrogel (1:1)	Coco-coir+hydrogel (1:1)		
		Onion 🍅	Garlic 🧄	Banana 🍌
Chia seeds	6.23±2.48	4.50±0.00	7.40±0.92	4.20±0.00
Flax seed	3.90±0.79	3.50±0.50	3.73±1.55	2.25±0.35
Gond katira	11.30±1.61	13.70±0.40	12.50±1.32	9.70±1.89
Arrowroot powder	12.98±1.46	10.92±1.50	8.67±1.46	8.44±1.05
Tapioca	8.00±3.00	6.10±1.76	14.00±2.00	4.00±0.14
Agar-agar	7.10±0.17	10.10±0.15	13.70±13.70	10.40±0.20
<i>Aloe vera</i> and corn starch	3.70±0.44	3.60±0.30	10.20±0.25	6.50±0.60
Gelatin+ agar-agar	5.75±2.79	4.15±1.51	6.58±1.96	3.25±1.53
Sanitary napkin	11.81±1.63	11.56±0.05	6.43±0.03	4.86±1.10

The shoot length of Fenugreek plants grown in presence of Aloe-vera +corn starch-based hydrogel (1:1) was observed to be higher as compared to control plants. The addition of bio-organic fertilizers of onion, garlic and banana peel powder to Aloe-vera +corn starch hydrogel (1:1) was found to be effective as Fenugreek plants were observed to be taller as compared to control (Table 8)

Table 8. Shoot length (cm) of Fenugreek in Aloe vera and corn starch based hydrogel

	After 2 days	After 4 days	After 6 days
Control	1.00	3.00	3.90
Coco-coir + hydrogel (1:1)	2.00	4.00	5.00
Onion	1.50	4.10	4.90
Garlic	1.50	4.00	5.20
Banana	1.50	3.10	4.90

3.6 Number of leaves

The average number of leaves observed showed an increase in Agar-agar (3) and Sanitary napkins (3) as compared to control when these hydrogels were taken in 1:1 ratio with Coco-coir. In 1:2 ratio composition, as compared to control an increase in average number of leaves was observed in Chia seeds (3), Agar-agar (3) and Arrowroot powder (3) based hydrogels

The bio-organic fertilizer prepared from onion powder was found to be effective in case of Chia seeds (3) and Sanitary napkin (3) hydrogel showed an increased number of average leaves per plant as compared to control. The bio-organic fertilizer prepared from garlic and banana peel powder was found to show an increased number of leaves in Arrowroot powder-based hydrogel (as shown in Figure 3).

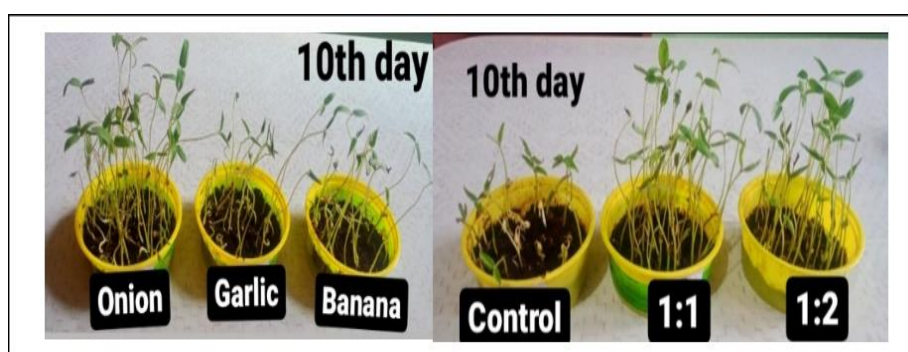


Figure 3. Ten days old Moong Bean seedling grown in presence of Gond katira hydrogel and bio-organic fertilizers showing difference in seeds germination, shoot length and number of leaves

3.7 Root length

The root length was found to be increased in hydrogels of Chia seeds (2.23 cm), Gond katira (1.92cm), Arrowroot powder (2.34 cm), Agar-agar (2.2 cm), Aloe vera + Corn starch (2.8 cm), Gelatin + Agar-agar (2.48 cm) and Sanitary napkin (2.04 cm) as compared to control when these hydrogels were taken in 1:1 ratio with Coco-coir.

In Coco-coir and hydrogels when taken in 1:2 ratio increased root length was observed in Gond katira (1.8 cm), Arrowroot powder (2.17 cm), Tapioca (1.93 cm), Agar-agar (1.8 cm), Aloe vera + Corn starch (4.6 cm), Gelatin + Agar-agar (2.2 cm) as compared to control (Table 9). The maximum root length was observed in Aloe vera + Corn starch (4.6 cm) and the minimum root length in Agar-agar (1.8 cm) & Gond katira (1.8 cm).

Table 9. Root length (cm) of moong bean plants in control and different hydrogels after 10 days

	Control	Coco-coir+hydrogel (1:1)	Coco-coir+Hydrogel (1:2)	Coco-coir+hydrogel (1:1)		
				Onion 🧅	Garlic 🧄	Banana 🍌
Chia seeds	2.00±0.87	2.23±1.46	1.95±0.61	2.08±0.93	2.18±1.56	2.06±0.90
Flax seed	3.27±0.65	2.50±1.50	0.00±0.00	2.43±0.40	1.57±1.36	1.65±0.21
Gond katira	1.00±0.15	1.92±0.17	1.80±0.10	2.51±0.29	1.62±0.42	2.07±0.10
Arrowroot powder	2.03±0.12	2.34±0.49	2.17±0.16	2.14±0.07	2.42±0.27	2.07±0.21
Tapioca	1.50±0.44	1.50±0.50	1.93±0.50	1.16±0.42	4.30±1.52	0.65±0.49
Agar-agar	1.10±0.15	2.20±0.10	1.80±0.06	2.70±0.26	3.10±0.10	2.80±0.17
<i>Aloevera</i> and corn starch	1.00±0.17	2.80±0.20	4.60±0.36	2.00±0.40	6.00±0.10	3.80±0.35
Gelatin+ agar-agar	2.07±1.10	2.48±0.63	2.20±1.05	2.15±1.03	2.38±1.54	2.04±0.90
Sanitary napkin	2.00±0.39	2.04±0.09	1.84±0.06	1.97±0.22	1.63±0.09	1.72±0.29

The root length in presence of bio-organic fertilizer of onion powder showed significant increase as compared to control in Gond katira (2.51), Arrowroot powder (2.14 cm) and Agar-agar (2.7 cm) based hydrogels. Garlic powder proved an effective bio-organic fertilizer in Arrowroot powder (2.42), Tapioca (4.3 cm), Agar-agar (3.1cm) and *Aloe vera* +Corn starch (6cm) (Table 9). In addition, hydrogel from Gond katira (2.07 cm), Agar-agar (2.8 cm), *Aloe vera* + Corn starch (3.8 cm), Gelatin + Agar-agar (2.04 cm) in presence of banana peel powder also showed increased root length. The maximum root length was observed in *Aloe vera* + Corn starch (6cm) and the minimum root length in Tapioca (0.65 cm).

Therefore, this study indicated that the root length was found to be increased significantly in the presence of hydrogels. (Figure 4).

Figure 4. Comparison of root length in *Aloe vera* + Corn starch hydrogel

In Fenugreek plants, the root length was found to be increased significantly in presence of *Aloe-vera* +corn starch hydrogel (1:1) as compared to control. The addition of bio-organic fertilizers of onion and garlic peel powder to *Aloe-vera* +corn starch hydrogel (1:1) was found to be effective in increasing the root length as compared to control (Table 10).

Table 10. Root length (cm) of Fenugreek plants in Aloe vera and corn starch based hydrogel after 6 days

	Root length (cm)
Control	1.50
Coco-coir + hydrogel (1:1)	3.50
Onion	3.00
Garlic	3.06
Banana	0.80

Gond katira or Gond is Tragacanth gum and is a jelly like colorless exudate obtained from the roots of this plant. The hydrogel can hold a high quantity of water for a very long time and therefore helps in better seed germination and root and shoot development in the initial stages of seedling establishment of a plant (Ozel et al., 2018).

Our results indicate that when seeds are germinated in the presence of hydrogels, the requirement for water is less as compared to the control. The increase in the shoot length, number of leaves along with root length indicates a better seedling established in the presence of natural hydrogels. Since seed germination and seedling establishment are the most important phases of the initial growth of plants and this is dependent on the availability of water, it is usually restricted by low levels of moisture/water in the soils.

Onion peel is a rich source of potassium, calcium, iron, magnesium and copper. It can be used for making fertilizer and use of this is a step towards zero budget organic farming and also solid waste management (Pellejero et al., 2017). Banana peels have the richest organic source of potassium. It has nutrients that are essential for healthy plants. When they are used, they decompose and add potassium, phosphorous, magnesium and nitrogen to the soil in a manner as a slow-release fertilizer. Using them also increase disease resistance, growth and productivity (Jenifer et al., 2014). Use of natural hydrogel as our study indicate may prove as an easy, low cost and eco-friendly way to establish the seedling development and subsequent productivity at the commercial level under conditions of water scarcity for sustainable agriculture (Kalhapure et al., 2016).

4. Conclusion

Due to expanding demands for water in Industrial sector, urban area and agriculture, availability of water has become a limiting factor for our crop productivity. Synthetic polymer-based hydrogels have been recommended for this purpose in agriculture for increasing water retention capacity and helping in plant water relation.

Various novel bio-degradable hydrogels were prepared that resulted in effective water holding capacity (up to 200-500 times). The hydration requirement for the soil-less media containing hydrogels was decreased as compared to control, specifically up to 1.7 times in media amended with *Aloe vera* and Corn starch-based hydrogel. The study of several plant growth parameters revealed that maximum shoot length and seed germination were shown in Arrowroot based hydrogel and maximum root length was shown in *Aloe vera* and Corn starch-based hydrogel. An increase in these growth parameters was obtained when onion, garlic and banana bio-organic fertilizers were used with hydrogels in the growth media.

This experiment has looked upon the possibility of the natural sources of hydrogels that showed promising results in sustaining seedling establishment during early stages of germination indicating that the bio-degradable, eco-friendly natural hydrogels can be tapped for in order to increase crop productivity.

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Author's declaration and contribution

The authors declare no conflict of interest. All the authors had contributed equally for the work. Similarly, entire author team agreed and gave their consent for the final version of the work.

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