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ENHANCING MOISTURE RETAINING CAPACITY OF BLACK COTTON SOIL USING HYDROGEL

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Abstract - *This paper study investigates the feasibility and effectiveness of using Natural hydrogel (Cellulose, Starch and Cellulose Starch Composite) to overcome water shortage and enhance the yield and quality of tomatoes as a sustainable alternative for toxic fertilizers. The study examines the use of three tomato samples: 1) with natural hydrogel 2) with artificial hydrogel and 3) without hydrogel. The materials were used to produce starch and cellulose are potato peels, corns, orange peels, aloe vera. The results show that the use of natural and artificial hydrogel improved the growth of tomato yield. The study also found that in tomato irrigation the use starch-cellulose based natural hydrogel reduced the consumption of water as compared to artificial hydrogel. The findings suggest that natural hydrogel can be a viable and sustainable alternative in agricultural fields, offering both engineering and environmental benefits.*

Key Words: hydrogel, Tomato irrigation, starch-cellulose based materials.

1.INTRODUCTION

Tomato is one of the major food crops of India, and it is an essential portion of the country's overall food security. It is a large water-consuming crop, particularly when cultivated using the drip irrigation method, with an average of 1000 to 1200 liters of water required to produce 1 kg of tomatoes (Government of India). The major tomato producing states are Maharashtra, Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, Madhya Pradesh and Assam. Tomato can be grown on a wide range of soils from sandy to heavy clay. However, well-drained, sandy or red loam soils rich in organic matter with a pH range of 6.0-7.0 are considered as ideal. Tomato is a warm season crop. The best fruit colour and quality is obtained at a temperature range of 21 24°C. Temperatures above 32o C adversely affects the fruit set and development. The plants cannot withstand frost and high humidity. It requires a low to medium rainfall. Bright sunshine at the time of fruit set helps to develop dark red coloured fruits. Temperature below 10 oC adversely affects plant tissues thereby slowing down physiological activities (Government of India).

Tomato Seeds are sown in June July for autumn winter crop and for spring summer crop seeds are sown in November. In the hills seed is sown in March April. About 250 300 g of seed are sufficient for raising seedlings for one hectare of land. Sowing should be done thinly in lines spaced at 10-15 cm distance. Seeds are sown at a depth of 2-3 cm and covered with a fine layer of soil followed by light watering by water can. Tomato is very sensitive to water application. Heavy irrigation provided after a long spell of drought causes cracking of the fruits. Hence it should be avoided. Light irrigation should be given 3-4 days after transplanting. Irrigation intervals should be according to soil type and rainfall, irrigation should be given 7-8 days interval during kharif, during rabi 10-12 days and 5-6 days during summer (Government of India).

Hydrogels are superabsorbent materials that can absorb and store a few hundreds of times their own weight in water. In indigenous agriculture, hydrogel is a product that has been designed and produced to increase crop productivity per unit of available water and nutrients, particularly in moisture stressed environments. Extreme weather events and droughts have been more common in recent decades, as has the frequency of such disasters. A number of research have been carried out to determine how climate change influences precipitation and irrigation patterns. A decrease in groundwater reserves in semi-arid regions and shifts in the spatial distribution of surface water have led to the prediction that an increase in irrigation storage will be critical in India if agricultural production is to maintain its current level in the face of increasing demand (Devineni et al., 2013). In recent years, it has been stated that the number of drought occurrences has grown over the past decade, and that the pattern of monsoon rainfall, which accounts for 80 percent of Nepal's total precipitation, has become more irregular since 2000. (Jha et al., 2016). Super Water Absorbent (SWA) hydrogels are cross-linked polymers exhibiting unusually high-water uptake abilities. these materials have found extensive use mostly in agriculture to retain moisture in the soil in arid and semi-arid regions (Sultana et al., 2016). If hydrogels are allowed to dry up, the influence they have on the body is diminished; consequently, irrigation is required to ensure the longevity of hydrogels. Hydrogels can be applied

to the soil either by mixing them in or by spraying them on. Hydrogels can be combined with micronutrients and insecticides while being applied with the spray technique.

Polymer hydrogels play an important role in agricultural sector and use as structural materials for creating a climate beneficial to plant growth and increasing irrigation water efficiency (Dehkordi, 2017). They have been established as a soil conditioner to decrease soil water loss and increase crop yield. Polymer hydrogels are hydrophilic networks with a high capacity for water uptake, which can absorb, swell and retain aqueous solutions up to hundreds of times their own dry weight of sample (Sun et al., 2012). Also, it minimized micronutrients from washing out to water tables and causes more efficient water consumption, reduction in irrigation costs (Koupai and Mesforoush, 2009) and improving plant viability, seed germination, ventilation and root development.

Hydrogels have high water-retention capability, displaying a sustained ability to release water and fertilizers (Sabadini, 2015). A simple meta-analysis of existing literature showed that the amount of published works related to the agricultural applications of hydrogel has increased by approximately 5 times, while the overall publications concerning hydrogel have increased by approximately 3 times. The availability of water for rainfed rivers is variable as a result of climate fluctuations, which are influenced by precipitation patterns. The combination of a sustainable water usage approach with alternative farming practices that can contribute to an improved crop production environment makes it necessary to investigate alternative approaches that can assist improve the environment. The most advantageous property of superabsorbent polymers lies in absorbing liquids several hundred times than their body weight and turning them into a gel. Therefore, it will keep or avoid water loss from the soil. the literature review, the problem statement and the objectives were formulated. Laboratory and field level experiments were performed to achieve the objectives. Through observations and experience from the preliminary tests.

2. LITERATURE REVIEW

[1] Reddy et al., (2021) presented the research on water consumption of rice by using superabsorbent hydrogel. In this research the author aimed to evaluate the swelling properties of hydrogel and its effects on growth of crop. This study was conducted at CHRIST, school of engineering and technology, Bengaluru during January-March 2020. Loamy soil was used for this study. The hydrogel used for the study was superabsorbent polymer hydrogel under the brand name “Magic hydrogel” with swelling ratio of 500. In this experiment the author used the filter to determine swelling ratio of hydrogel, The filter used for swelling test was “Atoz prime 1Mx1M nylon sheet”. Water used for the testing included deionized water, saline water and groundwater. The fertilizers used for the study were urea (46% nitrogen), diammonium phosphate (46% phosphorus) and muriate of potash (60% potassium). The paddy seeds used were of hybrid variety Ankur 13555. In This study the author found out the properties of soil using sieve analysis and specific gravity test as per Indian standards (IS-2720:1983). Seed treatment with hydrogel was done under laboratory conditions, this test was conducted to determine the optimal dosage of hydrogel for germination. The hydrogel swelling was studied by performing free-absorbency capacity measurements at consecutive time intervals. The water retention test determines the amount of water released by hydrogel under various temperature conditions. The result shows that the plant height at 2 weeks after sowing showed significant increase in height. The study concluded that the hydrogel can be advantageously used in soil conditioning as an effective way to protect irrigation water resources and to ensure food security.

[2] Reddy (2021) presented the research on application of hydrogel in paddy field for soil moisture retention and yield optimization. In this research the author aimed towards enhancing water retention using natural polymer hydrogel and its effects on paddy cultivation. This study was conducted at CHRIST, school of engineering and technology, Bengaluru during February 2021 to June 2021. Loamy soil was used for this study. The hydrogel used for the study was superabsorbent polymer hydrogel. The seeds from two rice varieties were selected, namely BPT5204 and NDLR07. In This study the author used randomized data control trial (RCT) method. it is a trial in which 6 subjects are randomly assigned in two groups: one (the experimental group) receiving the observations that is being tested, and the other (the comparison group or control) receiving an alternative (conventional) treatment. The two groups are then followed up to see if there are any differences between them in outcome. The water retention test determines the amount of water released by hydrogel under various temperature conditions. The result shows that Rice variety BPT 5204 responded favourably to when hydrogel was applied in soil. Hydrogel application with 40% less water supply had found to be optimum without compromising on the crop yield. The study concluded that the addition of hydrogel had a favourable effect on the plant, which grew at a faster rate as a result of the addition. The maximum plant growth was observed in paddy fields with a 20 and 40 percent shortfall in water. The use of NDLR07 as a drought-resistant crop that has been supplemented with hydrogel would help to prevent damage and loss as a result of drought. When supplemented with hydrogel, the BPT5204 strain has shown more tolerance to drought conditions.

[3] Ahmed and Fahmy (2019) Studied the research on applications of Natural polysaccharide polymer (Cellulose, Starch and Cellulose Starch Composite) to

overcome water shortage on the yield and quality of tomatoes. This study was conducted at J. Soil Science and Agriculture Engineering, Mansoura University during 2017/2018. Loamy soil was used for this study. The author used two different agricultural residues (Rice straws and Potato peels) to prepare natural polymers. In this experiment the author conducted four tests; without polymer as a control and with different polymer (Cellulose, Starch and Cellulose Starch Composite) under three different level of irrigation were used. Soil analyses has been done according to the specific gravity test, Oven drying method and Sand bath method to found out moisture content. The water retention test has been performed to determines the amount of water released by hydrogel for the specific natural polymer. Regarding the plant analysis, total soluble solids (TSS %) was measured in fresh fruit by Refractometer. The pH of tomato fruits juice was measured by digital pH meter. The juice was determined as percent of total weight of the fresh fruits. The result shows that the increase of yield when applied different polymers (cellulose, starch and cellulose/starch), this increase reached to 13.7, 14.7 and 20.5% compared to without polymers. Irrigation quality increased and decrease in total soluble solids and Ph. juice content improved significantly with applies of natural polymers. The use of natural polymers improved the water use efficiency of tomatoes. The study concluded and recommends that, reuse of some plant residues to produce natural and environmentally safe polymers and their application in agriculture to reduce plant irrigation requirements under this experiment up to 40% while maintaining the productivity of tomato compared to full requirements of irrigation without polymers.

[4] Sultana et al., (2016) presented the research effect of Super Water Absorbent (SWA) hydrogel on productivity and quality of Tomato. In this research the author aimed to improve the soil capability to retain water by adding SWA hydrogel. This study was conducted at Institute of Nuclear Science and Technology, Dhaka during august 2016. Silt Loam soil was used for this study. The hydrogel used for the study was SWA. In this experiment the author used the 5% Acrylamide (Aam) with 3% Carboxymethyl cellulose (CMC) as SWA. In this study the author carried out the Biochemical analysis to identify bacterial species on the basis of biochemical activities. The moisture content has been found out by performing oven drying method, The water retention test has been performed to determines the amount of water released by the SWA. The result shows that when SWA is mixed with soil the plant height, weight of roots, number of branches, number of leaves and yield of fruits of tomato plant showed higher values than that of the soil without SWA. It has also been observed that with and without SWA the elemental properties of soil gave almost the same values meaning that adding SWA did not affect the properties of soil. Regarding the quality of fruit, the food value (protein, ascorbic acid, iron) of green tomato showed no significant changes with and without SWA, although the significant increase in total phenol content of green tomato grown in SWA mixed soil indicates better antioxidative quality (To counteract the damaging effects of oxidation). The study concluded that adding SWA hydrogel to soil can improve the soil capability to retain water.

[5] Mahgoub (2020) presented the research on Effectiveness of Hydrogel Application on Tomato Growth and some Sandy Soil Chemical Properties under Drip Irrigation System. This study was conducted at the experimental site of Faculty of Agriculture of Suez Canal University, Ismailia during July 2020. Sandy soil was used for this study. The hydrogel used for the study was hydrophilic cross-linked biodegradable polymer hydrogel which can absorb water by 100 times the original weight in a short time. In this experiment the author used Drip Irrigation method and fertilizers (HG1=0.5F) for enhancing Nitrogen (N), Phosphorus (P), and Potassium (K) contents of tomatoes. In This study the author analysed the electrical conductivity of soil samples using Electrical Conductivity Meter (ECM). The result presented some growth parameters of tomato plant using hydrogel. In general, the number of plant branches in the case of adding hydrogel is higher than when adding fertilizers. The study concluded that the by hydrogel to soil, plant growth and some soil chemical properties were improved.

[6] Motamedi et al., (2021)

presented the research on Effect of hydrogel composite reinforced with natural char nanoparticles on improvement of soil biological properties and the growth of water deficit-stressed tomato plant. In this research the author aimed to investigate the effect of hydrogel-nano natural char composite (reinforced starch-based hydrogels with natural char nanoparticles) at three levels 0%, 0.3% and 0.6% (w/w) on nutritional and growth of tomato plant. This study was conducted at Agricultural Biotechnology Research Institute of Iran (ABRII) during July 2021. Saline soil was used for this study. The hydrogel used for the study was natural char nanoparticles (NCNPs) composites. the author conducted test on the growth of tomato plant using different levels of the nanocomposite hydrogels. The experimental treatments included (i) soil amendment factor (nanocomposite) at three levels: 0% ,0.3% and 0.6 % (w/w) and (ii) water-deficit stress factor at three levels: the plants watered with distilled water to maintain the soil moisture at 50% water holding capacity, the plants watered with distilled water to maintain the soil moisture at 75% water holding capacity and the plants watered with distilled water to maintain the soil moisture at 85% water holding capacity. The result presented that the synthesized NCNPs/hydrogel nanocomposite has increased tomato tolerance to water deficit stress. The NCNPs/hydrogel nanocomposite application reduced the negative impacts of water deficit stress. The study concluded that the

suitability of natural char as a cost-effective and biocompatible filler for the synthesis of high-performance starch based superabsorbent composites. In addition, the current study also confirms the positive effects of nanocomposites treatments on the tomato growth and survival under water deficit stress conditions.

[7] Shaaban et al., (2012) presented the research on Effect of hydrogels and organic composts on soil hydro physical properties and on production of tomato. In this research the author aimed to study the conditioning effect of hydrogels when mixed with or grafted on organic composts, on production and use efficiency of water and fertilizers by growing plants. This study was conducted at Horticulture Brasileira, Egypt during March 2012. Sandy soil was used for this study. The hydrogel used for the study was polyacrylamide K polyacrylate gel grafted on wooden waste compost. In this experiment the author used Trickle irrigation system (agro drip) and fertilizers Super phosphate (15.5% P2O5) and potassium sulphate. In This study the author analysed Some hydro physical properties of the soil related to structure stabilization, pore size distribution, moisture retention and water transmitting properties. The result presented yields of tomato were significantly increased by 1.35 times that of the control treatment (non-conditioned soil). The study concluded that the addition of polyacrylamide K polyacrylate gel grafted on wooden waste hydrogel to soil, plant growth and some soil hydro physical properties were improved.

[8] Bortolin et al., (2019) presented the research on Growth of tomato seedlings in substrates containing a nanocomposite hydrogel with calcium montmorillonite (NC-MMt). In this research the author aimed to investigate the growth and development of seedlings, tomato hybrid 'BRS Nagai', in substrates containing different amendments of hydrogel NC-MMt. This study was conducted at Embrapa Hortaliças, Brazil during January 2019. Black soil was used for this study. The hydrogel used for the study was NC-MMt hydrogel. In this experiment the author used Three substances peat moss, pine bark, and coconut peat. The result presented regarding the growth of crop the coconut peat-based and peat moss-based substances reached 89.4% and 88.9% respectively, differing from pine bark-based sample. pine bark may contain substances such as terpenoids, which can have adverse effects on plant growth in conjunction with hydrogel that may cause physical restrictions to the growing. The study concluded that Overall, peat moss-based and pine bark-based substrates resulted had higher value as compared to coconut peat-based sample and had a significant impact on growth of tomato crop.

[9] Chandra et al., (2023) presented the research on Growth and yield of tomato on soil amended with waste paper-based hydrogels. In this research the author aimed to retain and gradually release water and nitrogen for plant growth using freeze-dried hydrogels (FDH) and oven-dried hydrogels (ODH) hydrogels derived from paper waste. This study was conducted at conducted in a greenhouse during February 2023. The hydrogel used for the study was freeze-dried hydrogels (FDH), oven-dried hydrogels (ODH) which was made from Waste office paper was collected from an office on the university campus. The primary chemicals used for manufacturing the hydrogels (sulfuric acid, sodium hydroxide, and urea) were purchased from Millipore Sigma (Ontario, Canada). A water-soluble commercial N-P-K fertilizer (20-20-20) (Miracle Grow) was purchased from Home Depot, Montreal, Canada. The experimental treatments included 3 samples, i) freeze-dried hydrogels ii) oven-dried hydrogels iii) control sample (without hydrogels). The results indicated that FDH- 95% AWC treatment produced the highest average crop yield of 0.88 kg plant−1, compared to the ODH (0.32 kg plant−1) and control treatments (0.40 kg plant−1). FDH and ODH produced higher yields and saved 15 % and 20% of irrigation water (225mm), respectively, compared to the control treatment. The study concluded a clean technology whereby wastepaper can be recycled into biodegradable hydrogels to increase crop productivity.

3. AIM

1. To achieve sustainable irrigation of Tomato crop by enhancing the moisture retaining capacity of black cotton soil by using Hydrogels.

4. OBJECTIVE

1. To procure the materials like tomato seed, nursery bed, black cotton soil and hydrogel.
2. To evaluate the properties of soil, hydrogels, tomato and water to be used for irrigation.
3. To cultivate tomato crop in black cotton without hydrogel, with Starch and Pectin based sustainable hydrogel and with SWA hydrogel.
4. To compare the experimental test results of crops of all test samples

5. CONCLUSIONS

All the above-mentioned researches concluded that:

Hydrogels enhance soil water-holding capacity, which reduces irrigation frequency and stabilizes moisture levels, benefiting water-intensive crops like tomatoes and Rice (Reddy et al., 2021, Reddy 2021).

Hydrogels also aid water conservation by reducing evaporation and runoff, which is crucial in water-scarce regions. They can improve soil structure by preventing compaction and enhancing aeration, supporting overall plant health.

Synthetic hydrogels may be costlier and less eco-friendly compared to natural or hybrid options, though their water

retention efficiency can be advantageous. Natural hydrogels, while more environmentally friendly, may vary in effectiveness. About 2 grams of hydrogel is required to produce 1kg tomatoes (Ahmed and Fahmy 2019, Mahgoub 2020).

The effectiveness of hydrogels is influenced by climatic conditions, with higher temperatures potentially accelerating their degradation (Reddy et al., 2021).

Drip irrigation can significantly boost tomato yields, with increases ranging from 20% to 50%, depending on regional conditions (Sultana et al., 2016).

The impact of hydrogels also varies with soil type: they improve water holding in sandy soils but may not fully compensate for nutrient deficiencies; in loamy soils, they help mitigate water shortages and enhance root growth; in saline soils, they provide limited benefits due to the high salt concentration affecting plant water uptake (Sultana et al., 2016, Mahgoub 2020, Motamedi et al., 2021) .

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