Eco. Env. & Cons. 29 (January Suppl. Issue) : 2023; pp. (S36-S47)

ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i01s.007

Impact of Hydrogel on Agriculture – A review

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(Received 16 May, 2022; Accepted 13 July, 2022)

ABSTRACT

Water is one of the most essential natural resource, which is often costly and limiting particularly in arid and semi arid regions. Under climatic changing scenario, fresh water resources at global level is synchronizing day by day and creating water scarcity and transforming more irrigated area to rainfed. The use of water holding amendments like hydrogel polymer enhancing the water and nutrient use efficiency and will become more important over time, especially in arid and semi arid region. Hydrogel has unique characteristics that it retains water and nutrient from their surrounding area and will help in alleviating moisture stress of crop plants during prolonged dry period and where irrigation facilities are available this technology could reduce the number of irrigation applied to crops. The dose of hydrogel as suggested in the literature varies from 2.5 to 5 kg/ha depending on the soil texture. A lower dose is recommended for clayey soil while a higher dose is recommended for sandy soil. Nowadays water management is considered as one of the biggest challenge in arid and semi arid region of world, in fact by 2030 global water demand probably to be 50% higher than today, resulting in water scarcity. Many research finding confirmed that hydrogel not only used for saving of water/irrigation, but also have tremendous potential to improve the physical and biological properties of soil. In this paper, responses of hydrogel polymers on various crops are reviewed.

Key words: *Hydrogel, Nutrient uptake, Soil properties, Water productivity, Yield*

Introduction

Water scarcity is a global concern in context of increasing population and competitive demands from agriculture, industries sector and urban inhabitants. India has already entered in the shadow of the zone of physical and economic water scarcity. Irrigation water is becoming scarce and the world is looking for water efficient agriculture. Increasing food demand and declining water resources are major challenges for food security (Kreye *et al*., 2009). The issue of water management has assumed paramount importance and occupied the centre stage of politico-economic debates in the world. There is a tremendous pressure on agriculture sector to reduce its share of water and at the same time to improve total water productivity with increased water use efficiency.

The situation is forcing the researchers to search for viable technological interventions to meet future water needs. Poor water use efficiency is a serious bottleneck in realizing sustainable agricultural growth and food security for the future. Several agronomic practices have been developed and recom-

([1]Assistant Research Scientist, [2]Scientist) mended to improve water productivity in different crops. However, a holistic strategy to evolve integrated solutions for multiple problems has been elusive. The vertical effort practices *viz.*, irrigation and application of hydrophilic polymer increase the duration of moisture availability with an increase in the amount of available moisture in the soil.

Irrigation scheduling is one of the important managerial activities and affects the effective and efficient utilization of water by crops. Other than scheduling irrigation, to increase crop production under deficit soil moisture is to make plants grow better with the available amount of soil moisture. Correct management and by applying improved techniques for saving and conserving the moisture of soil and increasing the soil water holding capacity are among the activities for increasing the productivity and consequently exploiting limited water resources. New method in science of soil and water is using super absorbent materials (hydrogels) as reservoirs and prevention from water wastage and increase of irrigation efficiency (Bedi and Sohrab, 2004). The water absorbing products like hydrogel may be used as soil amendment to enhance water use efficiency (Huttermann *et al.,* 2006).

Hydrogel is three-dimensional, hydrophilic polymer, loosely cross-linked networks capable of imbibing large amounts of water or biological fluids. There are three groups of a polymer as follow: a) Starch–polyacrylonitrile graft polymers (starch co–polymers), b) Vinyl alcohol–acrylic acid co–polymers (polyvinyl alcohols) and c) Acrylamide sodium acrylate co–polymers – cross–linked polyacrylamides. These synthetic polymers found in form of crystals and available under several trade names *viz*., Super Absorbent, Pusa Hydrogel *etc.,* are collectively called hydrogel. 'Pusa Hydrogel' is a novel semi-synthetic super absorbent polymer developed by the Indian Agricultural Research Institute (IARI) and it has shown the potential to realize more yield per unit of input. This product displayed a swelling potential of minimum 350 times, often exceeding 500 times its weight in pure water. Notably, its swelling ratio increased with the rise in temperature up to 50 ^{o}C without any adverse effect on the polymer matrix structure.

It improves physical properties of soil, seed germination, seedling emergence rate, root growth and density that help plants to prolonged moisture stress. Rate of application of agricultural hydrogel depends upon the texture of soil – for clay soil: 2.5 kg/ha (at the soil depth of 6–8 inches). For sandy soil: up to 5.0 kg/ha (at the soil depth of 4 inches). In pot culture, mix 3–5 g/kg of soil before planting. While transplanting: Thoroughly mix 2 g (or according to recommended rate) of hydrogel per litre of water to prepare a free-flowing solution; allow it to settle for half an hour. Dip the roots of the plant in the solution and then transplant in the field. It enhances the crop productivity per unit available water and nutrients, particularly in moisture stress condition. As hydrogel gradually releases up to 95% of its stored water when its surroundings begin to dry out. But, when comes in contact with water again, it gets replenished. This process can last up to 2-5 years, by which time biodegradable hydrogel decomposes to CO_2, water and ammonia and potassium ions, without any residue, thus, environment friendly (Trenkel, 1997).

Hydrogel may prove as a practically convenient and economically feasible option to achieve the goal of agricultural productivity under conditions of water scarcity. The low application rate of hydrogel is effective for almost all the crops in relation to soil type and climate of India. Meager research work is available on hydrogel application on crops and soil properties and this work provides a comprehensive literature on the role of the hydrogel in agricultural sector. More than hundred references are cited in the whole text.

Effect of hydrogel on germination, root and growth parameters

Plant growth depends on cell division and cell expansion for which adequate water supply is essential (Singh and Singh, 1977) and is regularly restricted by low level of soil moisture mainly in arid and semi–arid regions. Hydrogel polymers enhance plant growth by swelling water holding capacity in soil and prolonged the time till reaching wilting point which increasing plants survival under water stress. Moreover, application of hydrogel polymer used to create a water reservoir near the root zone of plants, decrease osmotic moisture of soil and improve the capacity of plant available water and enhancement plant growth. According to Helalia and Letey, (1988), Yazdani *et al.* (2007) and Rakshith Kumar *et al.* (2018) uses of hydrogels improving plant viability, seed germination and root development mainly under arid environments. They observed that hydrogel is hydrophilic in nature with the capacity to absorb huge quantity of water almost

200–400 times its weight (Kalhapure *et al.,* 2016). Thus, its application in rhizosphere helps to retain moisture for a longer time period and helps overcome dry spells. Increased moisture availability in the surface soil layer enhanced germination of seed and resulted in increased plant population. Roy *et al.* (2019) highlighted there was an increment of 22% in plant population in with hydrogel plots (5 kg/ha) compared to without hydrogel plot. Likewise, a significant increase in root growth and seedling survival was also reported in ginger (Rakshith Kumar *et al.,* 2018), rice (Rehman *et al.,* 2011), wheat grass (Mengold and Sheley, 2007), barley and wheat (Akhter *et al.,* 2004) and cucumber (Al-Harbi *et al*., 1999) when soil was treated with hydrogel as compared to control. In contrast to this finding, no significant difference was observed between the control and the hydrogel applied plots in terms of root growth in wheat and castor (Ramanjaneyulu *et al.,* 2018 and Roy *et al.,* 2019).

Plant height of soybean, maize, potato, wheat and pearl millet increased with hydrogel application 2.5 to 5 kg/ha reported by Sivapalan (2001), Islam *et al.* (2011), Ezzat *et al.* (2011**)**, Roy *et al.* (2019) and Saini *et al.* (2020a). The main reason for increase in growth parameters might be attributed to water availability and indirectly nutrients provided by superabsorbent polymer, which have been reported to increase the activity of cell division, cell expansion and cell elongation, ultimately leading to an increased plant height. Similar results have been reported by Al-Harbi *et al*. (1999) and Barihi *et al*. (2013) in cucumber, Kumaran *et al.* (2001) in tomato, Sivapalan (2001) and Yazdani *et al*. (2007) and Amiri *et al.* (2013) in soybean. The positive effect of super absorbent on stem elongation is reported by Brar *et al.* (2001) and Malekian *et al.* (2012) in maize and Anupama *et al*. (2007) in chrysanthemum seedlings, Zhang *et al.* (2005) in *Parthenocissus quinquefolis.* Huttermann *et al.* (2006) in Aleppo pine, Waly *et al.* (2015) in rice, Lawrence *et al*. (2013) in *P. sylivestris* and *F. sylvatica* and Dabhi *et al.* (2013) in cash crops under semi arid region.

Yazdani *et al*. (2007) reported an increase in total dry matter of soybean with increase in polymer rate. Highest total dry matter was observed in soil treated with 225 kg/ha polymer as compared to control at all stages of irrigation intervals (6, 8 and 10 days). These results are tune with Allahdadi *et al.* (2005)**,** Nazrali *et al.* (2010), Saini *et al.* (2020b), Jalilian and Mohsennia (2013), Felora *et al.* (2013) and Mahalleh *et al*. (2011).

Effect of hydrogel on yield attributes and yield

Many of research finding have shown that yield component and yield in various crops affects with hydrogel application. According to Singh (2012), coating of pearl millet seed with 10 and 20 g of hydrogel per kg of seed resulted in the production of significantly higher effective tillers, ear length, test weight, grain and stover yield compared to control and water soaking treatment. Nazrali *et al.* (2010) revealed that application of polymer tended to increase 100-seed weight of sunflower as compared to control (without polymer). Similar results were also obtained by Allahdadi *et al*. (2005), Moazen *et al.* (2009), Yazdani *et al*. (2007) and Khadem *et al*. (2010) in corn and soybean crops. Sivapalan (2001) found that soybean grown in soil treated with 0.05, 0.1 and 0.2 per cent polyacrylamide (PAM) achieved higher grain production by about 6, 9 and 14 times greater, respectively over control. According to another study done by Watt and Peake (2001) on poly acrylamides and other soil-wetting polymers, incorporated into sandy potato fields, increased 102 per cent water retention in the soil around the root zone and subsequently, 25 per cent increase in tuber yield. These results are tune with the finding of Anupama *et al.* (2005), El-Hady and Wanas (2006) and Marques *et al.* (2013).

Rakshith Kumar *et al*. (2018) ascertain interactions of hydrogel with irrigation levels had a significant effect on number of tillers, fresh rhizome yield per plant with 5.0 kg/ha of Pusa hydrogel and irrigation at 14 days interval. Encouraging impact of hydrogel application on yield attributes of different crops has been noted by various researchers. Chrysanthemum grown in a soil-less medium with hydrogel application (0.5% wt/wt) showed increased number of flowers per plant as well as flower size compared to without hydrogel application (Anupama *et al.,* 2005). Increased yield in soybean, cucumber, rice, tomato etc. due to hydrogel application has been reported by several workers (Borivoj *et al.,* 2006**,** Yazdani *et al.,* 2007, Mandal, 2015 and Singh *et al.,* 2017). Increased spike length and the number of grains per ear and yield of wheat with hydrogel application @ 2.5 – 5.0 kg/ha have also been reported earlier (Borivoj *et al*., 2006, Dar *et al.,* 2017, Singh *et al.,* 2017, Jat *et al.,* 2018, Roy *et al.,* 2019), improvement in seed weight, seed yield and harvest index of chickpea (Mahmudirad *et al.,* 2014) and in rice crop also showed robust tillering due to more moisture retention with hydrogel @ 2.5 to 5.0 kg/ha (Rehman *et al.,* 2011, Waly *et al*., 2015, Saini *et al.* 2018). Mahalleh *et al*. (2011) obtained highest fresh fodder (16.12 t/ha) and biological yield (54.55 t/ha) of silage corn *var*. KSC with application of 200 kg/ha superabsorbent and this treatment had the highest water use efficiency and relative water capacity. In the same trend, application of 200 kg/ha of hydrogel in peanut were found to be significantly superior in respect of all yield characters (viz. seed yield, biomass yield, pod yield, number of branches per plant and 100 seed weight) in sandy soil of Iran with hot and arid climate (Langaroodi *et al.,* 2013).

Increase in yield with increase in polymer level can be a result of increased plants available water (Woodhouse and Jonhson, 1991); water is absorbed by the polymers that increase the water retention capacity of soils (El-Hady and Wanas, 2006, Bai *et al.,* 2010 and Han *et al.,* 2013). Polymers gradually release water and nutrients to increase the efficiency of water and fertilizer consumption which in turn results in higher yield (Islam *et al.,* 2011); this accords with El-Hady and Wanas (2006) on cucumber and El-Badea *et al.* (2011) on potato yield. Researcher confirmed that optimum supply of water and nutrient ensures increased cell division and hence better plant growth and yield components for the hydrogel amended plots. As significant amount of water hold by hydrogel structure and subsequently, putting the absorbed water into the soil around plant roots, thereby increasing soil's water holding capacity and providing a buffer against the product loss during the time between two irrigations, (Johnson and Woodhouse, 1990) and because of the uninterrupted water availability, plants obtained continuous supply of water and nutrients and thereby resulted in higher photosynthetic activity and more carbohydrate assimilation enhanced yield attributes.

Effect of hydrogel on fertilizer use efficiency, nutrient content and uptake

Hydrogel hydrophilic polymer materials act as carrier and regulate release of nutrients was will be helpful in reducing undesired fertilizer losses, increase in use efficiency and reduced the quantity of fertilizer while sus-taining vigorous plant growth (Kalhapure *et al.,* 2016). El-Saied (2016) stated that hydrogel improve chemical properties and nutritional status of the soil through lowering pH and its effects on nutrient availability, increasing organic matter content, organic nitrogen percent in the soil and increasing available N, P and K in treated soil. These results are in tune with the finding of Mikkelsen, (1994), Huttermann *et al*. (2006) and Yazdani *et al*. (2012). According to Bredenkamp (2000), hydrogel improves macro and micronutrient uptake especially nitrogen, potassium and phosphorus as Aqua-Soil TM retained up to 400 per cent more nitrogen and 300 per cent more potassium than standard quick and slow release fertilizers. Likewise, Dabhi *et al.* (2013) reported that super absorbent polymers influenced optimum use of fertilizers in cash crops in arid and semi-arid regions. Nutrient uptake and water-use efficiency improved in winter wheat when hydrogel was applied at the rate of 5 kg/ha in a sandy loam soil, while in a clay loam soil with the same dose of hydrogel application along with recommended dose of fertilizer 8.48% increase in yield was observed (Borivoj *et al.,* 2006). These results are conformity with Rani (2007), Eiasu *et al*. (2007), Khadem *et al*. (2010), Pattanaaik *et al*. (2015), Saini *et al*. (2018). Moreover, Marlon *et al.* (2012) confined that use of a water retaining polymer had a positive effect on *Corymbia citriodora* and it helped to reduce by at least 20 per cent the amount of routine fertilizer used by the commercial nursery. The water held in root zone of the crop and leaching of nutrients in the soil was also reduced (Kalhapure *et al.,* 2016). These are in agreement with the find of Huttermann *et al*. (2006), Yazdani *et al*. (2007) and Islam *et al.* (2011).

Reason for increase in nutrient availability of some nutrients either present in soil or added in the form of relatively insoluble fertilizers due to partial retardation of gas exchange between soil and atmosphere as a result of increasing soil moisture and decreasing soil macro-porosity may favor transformation of some plant nutrients, such as NO_3^- and some micro-nutrients to their reduced forms i.e. NH_4^+ and other forms of micro-nutrients having lower equivalency, hence decreasing the loss of $No3^-$ by leaching and increasing the availability of other nutrients (Boatright *et al.,* 1995 and El-Hady *et al.,* 2006).

Effect of hydrogel on soil moisture studies

Hydrogel is hydrophilic in nature with the capacity to absorb huge quantity of water almost 200–400 times its weight (Kalhapure *et al.,* 2016). Thus, its application in rhizosphere helps to retain moisture for a longer time period and helps overcome dry spells Jamnongkan and Kaewpirom (2010). Increased moisture availability in the surface soil layer enhanced germination of seed and resulted in increased plant population. Roy *et al.* (2019) reported that hydrogel application increased moisture availability in the surface soil layer enhanced germination of wheat by 22% as compared to without hydrogel application. Similarly, application of 5 kg/ha of hydrogel significantly increases soil moisture content at different depths of soil (viz. 0–15, 15–30 and 30–45 cm) at all stages of crop growth in fodder sorghum (Dass *et al.,* 2013).

Guiwei *et al*. (2008) reported that amendment of soil with superabsorbent polymers reduced number of irrigation, prolonged the duration of water evaporation and wilting symptoms. As increase in water holding capacity due to hydrogel amendment significantly reduced the irrigation requirement of many plants (Taylor and Halfacre, 1986). Likewise, Kumaran *et al*. (2001) reported Hydrophilic polymer significantly reduced the number of irrigation frequency in tomato by increasing water holding capacity of soil which was in accordance with the results observed by Sivapalan (2001) and Jahangir *et al.* (2008). Use of hydrogel increased the amount of available moisture in the root zone resulting in longer intervals between irrigations (Abedi-Koupai and Sohrab, 2004, Allahdadi *et al*., 2005 and El-Hady *et al*., 2009).

Bhardwaj *et al*. (2007) stated that hydrogels function as an additional water reservoir for the soil-plant-air system. He reported that water retained by polymers when mixed with sand ranged between 40 and 140 kg kg^{-1}. Abedi Koupai *et al.* (2008) reported that application of 4 and 6 g kg^{-1} of Superab A200 (polymer) addition in sandy loam soil enhanced the available water content by 2.2 and 2.3 times as compared to the control. Hayat and Ali (2004) reported that 30 to 850 per cent increase in moisture contents and 17 per cent elevation in saturation percentage. They found that polymer Aquasorb absorbs water slowly and the water retained increases with time as well as it varied from 83 to 219 times of its weight during 30-210 minutes. Likewise, Ekebafe *et al*. (2011) reported an increase of 171 to 402 per cent in water retention capacity when polymers were incorporated in coarse sand.

According to Akhter *et al.* (2004), water absorption by hydrogel was rapid and highest which increased the moisture retention at field capacity linearly and delayed wilting stage by 4-5 days in seedling stage compared to control condition. Hydrogels help plants withstand extended moisture stress by delaying the onset of permanent wilting point and reducing irrigation requirements of crops due to reduced water loss through evaporation. The water held in root zone of the crop and reduced leaching of water and nutrients in the soil. Waly *et al.* (2015) conducted an experiment on rice plant and reported that addition of one per cent hydrogel to sandy soil under trial condition was effective tool to reduce water leaching from soil. Similarly results also confirmed by Rehman *et al.* (2011).

Agaba *et al*. (2011) stated that superabsorbent polymers (SAPs) could absorb significant amounts (up to 2,000 g/g) of water, therefore these are considered very suitable for applications in horticulture and agriculture. Addition of polymer to peat soil decreased water stress and increased the time to wilt (Karimi *et al*., 2009). Wu *et al*. (2008) reported that chitosan hydrogels were potential natural alternatives to polyacrylamide products that were used to improve the water retention in sandy soils and containerized growing media in ornamental horticulture. Dabhi *et al.* (2013) indicated that super absorbent polymers influenced hydrophilic property, irrigation efficiency, effects under drought stress and optimize water use efficiency of cash crops in arid and semi-arid regions. Orikiriza *et al*. (2009) suggested hydrogel amendment enhances the efficiency of water uptake and utilization of photosynthetic of plants grown in soils which have water contents close to field capacity. By application of superabsorbent polymer, high water retention capacity and protection against drought was observed by various researchers in field locations. Johnson and Veltkamp (1985) advised that addition of hydrogel at the rate of 2 g/kg improved the water holding capacity of sand from 171% to 402%. An experiment was conducted by Bhat *et al.* (2004) on *Conocarpus lancifolis* and highlighted that incorporation of 2 g hydrogel reducing amount of irrigation water by 15 per cent or 3 g hydrogel and reducing irrigation by 30 per cent was profitable in cucumber under stress condition as compared to control plants. These results are tune with finding of Koupai *et al.* (2006), Abedi-koupai and Asad (2008) and El-Hady *et al*. (2009), Agaba *et al.* (2011), Lakshmi (2011) and Vijaylakshmi *et al.* (2012).

On the other hand, Ramanjaneyulu *et al.* (2018) studied on rainfed castor and clearly indicated that hydrogel application failed to enhance the seed yield of castor, though it helped to slightly improve the soil moisture content and couldn't beneficial for deep rooted and long duration crops like castor. These results are in agreement with that of Ingram and Yeager (1987) and Wang (1987) who reported that despite various beneficial effects of hydrogel addition, studies have shown little or no benefit with hydrogel addition.

Effect of hydrogel on soil properties

Agricultural hydrogels are not only used for water saving in irrigation, but they also have tremendous potential to improve physico-chemical and biological properties of the soil. According to various study on Agricultural hydrogels proved that it can change the soil properties through various mechanisms like Implement water–holding capacity of the soil (Hayat and Ali, 2004), Increasing soil permeability (Abd, 2006), Improving water retention on different soil types (Han *et al.,* 2010), Increase the water use efficiency (Koupai *et al.,* 2006), Increase irrigation intervals due to increasing the time to reach a permanent wilting point (Barakat *et al.,* 2015), Minimizing soil erosion and water run–off (Sojka and entry, 2000), Implement soil penetration and infiltration (Zhang and miller, 1996), Decrease soil compaction tendency (Ekebafe, 2011), Improving soil drainage (Akhter *et al.,* 2004), Support crop growth performance under reduced irrigation conditions (Koupai *et al.,* 2006), Enhance nutrient retention as a result of solute release from hydrogel polymer particles and delay the dissolution of fertilizers (Wang and Wang, 2009). Apart from this, it acts as soil conditioners and improves the physical properties of soils *viz*., porosity, bulk density, water holding capacity, soil permeability and infiltration rate. They improve the crop growth by increasing water holding capacity in soil and delay the wilting point in drought stress (Boatright *et al*., 1997). Many authors have reported positive (Rehman *et al*., 2011, Singh, 2012 and Langaroodi *et al*., 2013) and negative (Mandal, 2015) results in terms of moisture conservation and yield improvement in several crops with an exception of economic feasibility.

El-Hady *et al*. (2009) stated that hydrogel has the properties of improving the mechanical strength of the soil *i.e.,* decreasing both penetration resistance and compressive strength of the soil surface to be suitable for soil management practices and root growth and distribution. The bulk density of loamy and sandy soils reduced with polyacrylamide addition as compared to control while there was small increase in bulk density of clayey soil. Hayat and Ali (2004) observed that 8 per cent reduction in particle density along with 4 to 80 per cent reduction in bulk density in the soil treated with polymer as compared to non-treated soil. Conversely, porosity increased with increasing polyacrylamide doses for clay loam and sandy soil. However, macro pore size increased in clay soil while, it decreased in clay loam and sandy loam soil (Uz *et al*., 2008).

Combined effect of irrigation, fertility and hydrogel levels

Irrigation and fertilization are most important component for growth and development of plant. Both this components are interlinked with each other and having synergetic relationship under rainfed condition. Application of agricultural hydrogels can absorb minimum of 400 times of their dry weight of pure water and gradually release it according to the needs of the crop plant, enhance water and nutrient use efficiency and easily availed to plant in scarcity condition hence they are very suitable for semi-arid and arid regions (Dehkordi, 2016). Hydrogels help plants withstand extended moisture stress by delaying the onset of permanent wilting point and reducing irrigation requirements of crops due to reduced water loss through evaporation.

A study conducted by Taylor and Halfacre, (1986) observed that increase in water holding capacity of soil due to hydrogel significantly reduced the irrigation requirement of many plants. DWR (2013) advised that equivalent grain yield of wheat wheat with four irrigations without hydrogel was obtained with only two irrigations when 5 kg/ha of hydrogel was applied in northwestern, central and peninsular zones of India. A field demonstration on farmers' field at different locations in Uttar Pradesh conducted by ICAR evidenced that soil application of hydrogel @ 5 kg/ha can save two irrigations in wheat without reducing the grain yield. In addition of hydrogels with irrigation to coriander increases water availability, reduces percolation losses, leaches ions and improves soil aeration and drainage (Rostampour, 2013). Similar results are in agreement with finding of Cookson *et al.* (2001), Bhat *et al*. (2004), Azevedo *et al.* (2002), Orikiriza *et al.* (2009) and Mao *et al*. (2011).

Cookson *et al.* (2001) evaluated the effect of hydrophilic polymer application and irrigation rates on yield of field grown okra and reported that polymer treated crops required 25 and 50 per cent less water in summer and winter, respectively as compared to control condition. Rostampour (2013) reported that irrigation level and SAP had significant effects on sorghum. The results indicated that irrigation to meet 80 per cent of the water requirement with 75 kg/ha SAP may provide a desirable dry matter. Moreover, reducing irrigation amount from 100 to 85 per cent of crop water requirement caused an increase in marketable yield of cucumber relative to that of control equal to 38.6, 54.2 and 78.3 per cent when 2, 3 and 4 g of hydrogel crystals were incorporated, respectively.

Effect of hydrogel on soil biological properties and their residual effect

Microorganisms such as bacteria, fungi and actinomycetes influence profoundly the physical, chemical and the biological properties of soils. Activities of such organisms include the decomposition of plant residues and other organic materials, as well as the formation of humus. Since most of the biological reactions in the soil are enzymatic changes, therefore enzyme activity could be considered as important parameter to characterize the biological activity of the soil.

An experiment was conducted by Borivoj *et al.* (2006) approved that different enzymatic activities which are indicators of microbial population in the soil (viz. acid phosphatase, alkaline phosphatase, dehydrogenase, protease and urease) are increased with the application of hydrogel in sandy soils. El-Saied *et al.* (2016) conducted experiment on effect of paddy straw based hydrogel on biochemical properties of soil. The results obtained show that, hydrogel increase organic matter (OM), improving biological activity of the soil expressed as total count of bacteria and counts of Azotobacter *spp*., phosphate dissolving bacteria (PDB), fungi and actinomycetes/g soil as well as the activity of both dehydrogenase and phosphatase. Similarly, Abd *et al.* (2004) and El-Hady *et al.* (2006) also monitored increased in biological/microbial and dehydrogenase and phosphatase enzymatic activity in root zone of plant with hydrogel.

Hydrogels are environment friendly Biodegradable hydrogels contain labile bonds either in the polymer backbone or in the cross-links used to prepare the hydrogels. The labile bonds can be broken under physiological conditions either enzymatically or chemically over a period of time. End-products after degradation are CO_2, water and ammonia (Ekebafe *et al.,* 2011). Acrylamide, a monomer used for hydrogel preparation is neurotoxic, but polyacrylamide itself is non-toxic. The polyacrylamide can never reform its monomer. Hence there is no residual amount of acrylamide present in the soil after degradation of hydrogel, especially when cellulose is used as backbone. Acrylamide residue is also not detected in crop products which are grown with hydrogel application.

Economic feasibility

The information on economic evaluation of hydrogel application in various crops across the globe is meagre. Though various authors have reported positive reports on yield improvement across the globe, its economics has received less attention. Ramanjaneyulu *et al*. (2018) confined that minimum increase in seed yield by 200 kg/ha required to compensate the increased cost due to hydrogel addition. Further, an increase in seed yield by 400-500 kg/ha is required to achieve higher net returns and B:C ratio. Such results were also reported by Islam *et al*. (2011) who concluded that optimum dose of super absorbent polymer for maize cultivation was 30 kg/ha and lower (10-20 kg/ha) or higher (e"40 kg/ha) would neither be sufficient nor economical. Furthermore, Jat *et al.* (2018) stated that each unit increased in hydrogel application from 0 to 5 kg/ha enhanced the seed yield of mustard however; net returns and BCR were not increases significantly probably owing to more cost of hydrogel which increased the cost of cultivation resulted less net returns and benefit: cost ratio. Rohith Kumar (2015) concluded that higher B:C ratio of 2.15 was obtained without hydrogel application as compared to that of hydrogel applied @ 10 kg/ha (1.86), 15 kg/ha (1.72), 20 kg/ha (1.52), 25 kg/ha (1.36) and 30 kg/ha (1.24) in *rabi* maize in Bihar, India. From this reviews it is clearly indicated that high cost of hydrogel has been an inhibiting factor that has drastically affects their universal use in agriculture.

Conclusion

In conclusion, Agricultural hydrogels are eco-friendly, because they are naturally degraded over a period of time, without leaving any toxic residue in the soil and crop products. Various authors indicated that application of hydrogel enhanced the seed yield of various crop, though it helped to improved soil moisture content in soil, reduced the number of irrigation and enhance the inputs use efficiency. However, in terms of economics, it's always increase farmer's financial burden, but does not significantly bring an augment of the crops yield if hydrogel is utilized without supply of fertilizers. In view of higher cost, its' usage can be promoted only in high value crops which are grown under protected structures like shadenets or green houses or polyhouses. Future research works on identification of low cost material need to be carry out considering its degradation life.

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