EFFECT OF HYDROGEL AND MULCHING ON MAIZE (*Zea mays* L.) IN SANDY SOIL

by

RAJAP SHIVA KUMAR

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"EFFECT OF HYDROGEL AND MULCHING ON MAIZE (*Zea mays* L.) IN SANDY SOIL"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

R. Shiva Kumar

Rajap Shiva Kumar
(2016-11-123)

Padannakkad
Date:29-06-2018

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CERTIFICATE

Certified that this thesis entitled **"EFFECT OF HYDROGEL AND MULCHING ON MAIZE (*Zea mays* L.) IN SANDY SOIL"** is a record of research work done independently by Mr. Rajap Shiva Kumar under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Padannakkad

Date: 29/06/18

Dr. Bridgit. T. K.
(Major Advisor, Advisory Committee)
Professor
Department of Agronomy
College of Agriculture, Padannakkad

CERTIFICATE

We, the undersigned members of the advisory committee of Mr. Rajap Shiva Kumar, a candidate for the degree of **Master of Science in Agriculture** with major in Agronomy, agree that the thesis entitled **"EFFECT OF HYDROGEL AND MULCHING ON MAIZE (*Zea mays* L.) IN SANDY SOIL"** may be submitted by Mr. Rajap Shiva Kumar, in partial fulfilment of the requirement for the degree.

Ratheesh 29/06/18

Dr. Bridgit, T. K.
(Chairman, Advisory Committee)
Professor and Head
Department of Agronomy
College of Agriculture, Padannakkad

Shri. Ratheesh, P. K.
(Member, Advisory Committee)
Assistant Professor,
Department of Agronomy
College of Agriculture,
Padannakkad

Sudarsana Rao 29/06/18

Dr. G. V. Sudarsana Rao
(Member, Advisory Committee)
Professor and Head
Department of Plant Physiology
College of Agriculture, Padannakkad

29/6/18

Dr. Binitha, N. K.
(Member, Advisory Committee)
Assistant Professor
Department of Soil Science and
Agricultural Chemistry
College of Agriculture,
Padannakkad

P. Subramanian 29/6/18

EXTERNAL EXAMINER
Dr. P. Subramanian
Principal Scientist
CPCRI, Kasaragod

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LIST OF ABBREVIATIONS

%	-	Per cent
@	-	At the rate of
₹	-	Rupees
BCR	-	Benefit: cost ratio
BSS	-	Bright sun shine
CEC	-	Cation exchange capacity
cm	-	Centimeter
cm^2	-	Square centimeter
DAS	-	Days after sowing
DHM	-	Deccan Hybrid Maize
EC	-	Electric conductivity
et al	-	And others
ET	-	Evapotranspiration
FC	-	Field capacity
Fig	-	Figure
FYM	-	Farmyard manure
$g\ cc^{-1}$	-	Gram per cubic centimeter
$g\ g^{-1}$	-	Gram per gram
$g\ kg^{-1}$	-	Gram per Kilogram
$g\ plant^{-1}$	-	Gram per plant

g	-	Gram
ha^{-1}	-	Per hectare
K	-	Potassium
K_2O	-	Potash
KAU	-	Kerala Agricultural University
kg ha^{-1}	-	Kilogram per hectare
kg m^{-2}	-	Kilogram per square meter
kg^{-1}	-	Per kilogram
L.	-	Linnaeus
LAI	-	Leaf Area Index
lit^{-1}	-	Per liter
Ltd.	-	Limited
m	-	Meters
M	-	Million
m^{-2}	-	Per square meter
ml	-	Milli liter
mm	-	Milli meter
N	-	Nitrogen
NS	-	Not significant
^{o}C	-	Degree Celsius
^{o}E	-	Degree East

^oN	-	Degree North
P	-	Phosphorous
P_2O_5	-	Phosphate
plant^{-1}	-	Per plant
Pvt.	-	Private
PWP	-	Permanent wilting point
RARS	-	Regional Agricultural Research Station
RBD	-	Completely Randomised Block Design
RDF	-	Recommended dose of fertilizers
RLWC	-	Relative Leaf Water Content
₹ t^{-1}	-	Rupees per ton
SE	-	Standard error
t ha^{-1}	-	Tonnes per hectare
v/v	-	Volume by volume
VPD	-	Vapour Pressure Deficit
w/w	-	Weight by weight
WUE	-	Water Use Efficiency

INTRODUCTION

1. INTRODUCTION

Maize (*Zea mays* L.), queen of cereals, is the third important cereal crop in India followed by rice and wheat. India occupies fourth, sixth, and tenth places in area, production, and productivity respectively in the world (2014). It is cultivated in an area of 8.55 M ha. in 2014-15 and has a production of 21.81 M tons with an average productivity of 2510 kg ha^{-1} in 2015-16. The Minimum Support Price for maize in India during 2017-18 is ₹ 14.25 kg^{-1} (DES, 2017). Among the states in India, Karnataka occupies first position in area and production while Tamil Nadu ranks first in productivity. It is a crop having a variety of uses such as food for man, poultry, cattle feed, dairy products, industrial raw materials etc. Though maize is not a major crop of Kerala, maize grain products and speciality maize types like sweet corn, baby corn and popcorn are consumed by the people mainly in urban and sub urban areas. Owing to the increasing demand of maize in the market, the rice fallows can be effectively and economically utilized for maize cultivation, which is otherwise kept as fallow.

The issue of water management has assumed paramount importance and occupy the centre stage of politico-economic debates in world. The sharp fall in groundwater levels due to excessive removal for agricultural and other uses coupled with the high cost of fuel and electrical energy used in drawing groundwater and poor water use efficiency (WUE) due to wasteful practices are affecting the economics of water use in all spheres of human activity. The situation is forcing the researchers to search for viable technological options to meet future water needs. Poor use efficiency of water is the major bottleneck in attaining sustainable agricultural development, food safety and security in future. These goals can be achieved only with the rational and scientific management of production inputs. Many agronomical practices were developed and suggested to increase WUE in crops. However, a complete strategy to develop combined solutions for several difficulties has been indefinable. The practices like limited irrigation scheduling, application of mulches, anti-transpirants and hydrophilic polymer has increased the duration of moisture availability with an increase in the amount of available moisture in the soil.

Maize appears to be relatively tolerant to water deficits during the vegetative and ripening period. But studies have revealed that irrigation has improved maize yields significantly. Coarse textured sandy soils are often prone to water scarcity. Hence it is important to increase the water productivity. Hydrogel (super absorbent polymer), a water retaining, cross linked poly acrylamide, hydrophilic biodegradable amorphous polymer which can absorb and retain water about 400 times of its original weight and 95 % of absorbed water was made available for crop (Johnson and Veltkamp, 1985). Hydrogel not only increases the quantity of accessible moisture in root zone of crop, but also improves the fertilizer use efficiency and the physical properties of soil and soil less media. Hydrogels are reported to be a new technology to improve the WUE and to reduce the irrigation frequency. Hydrogel, in sandy soil increase its water holding capacity as a miniature water reservoir, thus influencing the infiltration, permeability, and density of soil (Narjary *et al.*, 2012). Hydrogels are environment friendly, principally produced from manufactured polymer and a certain moderately degraded by both living and non-living factors of environment, over a certain period of time (Narjary *et al.*, 2015). The availability of water in soil is the most important input for plant growth. Agricultural hydrogels have incredible potential to increase physical, chemical and biological properties of soil along with storage of water (Kalhapure *et al.*, 2016).

Mulching the crops with locally available materials is a common practice among farmers to reduce moisture loss and soil erosion. Being a relatively new technology, the efficiency of hydrogel application to agricultural lands should be compared with mulching practices. Hence, with the following objective this experiment was conducted.

- To study the effect of hydrogel (super absorbent polymer) and mulching on soil moisture status, growth and yield of maize.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In this chapter, efforts have been made to review the outline of research carried out by the earlier workers and their findings on the given research theme which will be helpful and is directly linked with the objectives are presented.

The literature on hydrogel, mulching, their effect on growth and yield of maize and also on the physical and chemical properties of the soil are reviewed here.

2.1 EFFECT OF HYDROGEL ON MAIZE

2.1.1 Characteristics of super absorbent polymer - hydrogel

Polymer is the substance which absorb and hold high amount of liquid based on its relative mass. The liquid absorbed by polymer can be water or an organic liquid (IUPAC, 2004). Three different classes of superabsorbent polymers are normally utilised *viz*. natural, semi-synthetic and synthetic polymers. Manufactured polymers are present in the form of tiny beads or crystals which are available under several trade names like root watering, drought crystals and super absorbent polymers, collectively known as hydrogels. These hydrogels are having high capability to absorb water when water is available and make that absorbed water available to plants over the period of time (Akhter *et al*., 2004).

According to Wallace (2000), presently 80 per cent (%) of water resources are available in the world for supporting irrigated agriculture. As resources of water decreases, water saving agriculture is required for the sustainable growth of human societies. Besides, due to climate changes droughts are predicted to increase (Gornall *et al*., 2010).

Initially hydrogel was the material which absorb 20 times more water than its own weight. Because of the availability of more cross-linked polymer having high water holding capacity increased to 400 to 2000 times than its weight and its less cost has revived interest on the utilization of hydrogel in Agriculture (Dar *et al.*, 2017).

Unlike hydrogel used in hygienic applications having the capacity to absorb fluid and hold it with high pressure, the agricultural hydrogel not only has the capability to absorb water, but also to discharge water constantly to the plants, based on its requirements (Kalhapure *et al.*, 2016).

Johnson and Veltkamp (1985) stated that hydrogel is a water holding, amorphous and biodegradable polymer which can absorb and hold water about 400 times than its original weight and at least 95 % of absorbed water is made available to the crop within the 15 bar tension which is permanent wilting point (PWP).

When hydrogel is mixed with soil, an amorphous gelatinous mass is formed on hydration and is having the capacity to hold it for a longer period of time in soil. Because of its capacity to absorb and release water for a longer period, hydrogel acts as a slow releasing water source in the soil. Application of hydrogel decreases the frequency of irrigation in almost all the crops, so it reduces the time and currency expend on water application and labour charge (Dar *et al.*, 2017).

In early 1960's, an American enterprise "Union Carbide" introduced the super absorbents in to the markets. Hydrogel production was started at the later period of twentieth century and were manufactured from the chemically altered starch and cellulose, and from other polymers like polyvinyl alcohol or polyethylene oxide. Presently, hydrogels are prepared from moderately nullified, less cross-linked polyacrylic acid and are water swelling. Polyacrylamide $(C_3H_5NO)_n$ formulations with longer-chain polymers which are more active and required in small doses compared to older polyacrylamide formulation which were required in large quantities per hectare (Wallace and Wallace, 1986). Polyacrylamide formulations are extensively used as synthetic hydrogel and is a polymer made from many acrylamide subunits. It is manufactured as a simple linear structural chains or cross-linked. Simple linked polyacrylamide is not used as a hydrogel for water absorption because it dissolved in water. The N, N′-methylenebisacrylamide cross-linked polymers are manufactured as hydrogels. These were made by imbedding and crosslinking of polyacrylamide on to a cellulose derived backbone polymer chain, which is carboxymethyl cellulose. Acrylamide is toxic (neurotoxic), while polyacrylamide is non-toxic (Kalhapure *et al.*, 2016).

Use of hydrogel is not effective when hydrogels are used as dry granules or mixing them within the whole root zone (Flannery and Busscher, 1982). Improved effects were found when the hydrogels were layered and applied few centimeters beneath the soil surface. Water absorption by hydrogel was fast in distilled water and reached to the maximum in 4 hours, but it needed 7 and 12 hours in tap and saline water respectively. As the salinity of water increases water absorption by hydrogel decreases. Highest absorption is in distilled water (505 g g^{-1}) followed by tap water (212 g g^{-1}) and saline water (140 g g^{-1}) in 1st hydration cycle (Akhter *et al.*, 2004). When hydrogel absorbs water contains Ca^{++} and Mg^{++} ions, these ions react with negative sites of polymeric chain resulted in the formation of insoluble salts and these salts can block the negative ion sites of polymer chain. As the salinity of water and upcoming cycles of wetting and drying process increases, the blockage of polymeric chains increases, finally the water absorption capacity of hydrogels decreases (Kalhapure *et al.*, 2016).

In soil, hydrogel particles are considered as "miniature water reservoirs". From these minute water reservoirs plants absorb water by the process of osmotic pressure difference and favour the uptake of nutrients from soil by retaining the nutrients tightly and delays its dissolution. Consequently, plants can absorb more amount of nutrients, resultant in enhanced plants growth (Ekabafe *et al.*, 2011).

2.1.2 Effect of hydrogel on growth and growth parameters of maize

Under limited irrigation, plant existence rate was 1.4 to 1.6 times greater with hydrogel application (Callaghan *et al.*, 1988). Boatright *et al.* (1997) reported that application of hydrogel enhanced growth of crop by increasing the water holding capacity of soil and extending the period to wilting point in drought stress conditions.

Incorporation of hydrogel in to the soil enhanced the water and nutrients status of the soil and those were made available to the crop as per the requirement of crop (Gehring and Lewis, 1980). Ability of water absorption and dry matter production are the optimistic crop reactions of hydrogel resulted in increased plant growth (Johnson and Veltkamp, 1985).

Hydrogel application enhance the seedling growth and crop establishment through increased water holding capacity of soil and regulated water supply to the plants (Woodhouse and Johnson, 1991). Enhanced seedling emergence and growth were observed in barley by Akhter *et al*. (2004) and in maize by Mazen *et al*. (2015).

Increased growth of maize was observed with increased concentration of hydrogel up to 0.4 %. The maximum root length was observed with 0.4 % hydrogel application and an increase of 90.6 % was obtained in the root length of maize than the control. Water content of maize plants and dry matter production were greatly improved by all hydrogel treatments used in sandy soils (Mazen *et al*., 2015).

In maize, water stress reduces plant height, leaf area, growth and yield (Cattivelli *et al*., 2008). Results showed that hydrogel application had positive effects on dry matter production and grain yield of maize by maintaining soil moisture during the vegetative growth period (Dragicevic *et al*., 2011). It also significantly increased the plant height, stem diameter, leaf area, harvest index and RLWC, as well as protein, sugar and starch contents in grain (Islam *et al*., 2011; Mao *et al*., 2011; Kumari *et al*., 2017).

Application of hydrogel results in significantly higher emergence count (180 m^{-2}), plant height (79 cm), effective tillers (264 m^{-2}), grains per panicle (69), grain yield (2.33 t ha^{-1}) of aerobic rice as compared to control (Rehman *et al*., 2011). Coating of bajra seeds with hydrogel @ 10 and 20 g kg^{-1} seeds significantly increased the number of effective tillers, ear length, test weight, grain and stover yield compare to control and water soaking treatment (Singh, 2012).

Leaf area is a good indicator of photosynthetic capacity of the plant. In soybean application of hydrogel significantly increased the leaf area and other growth parameters like crop growth rate, harvest index, total dry matter and yield (Yazdani *et al*., 2007). He also studied the influence of hydrogel on water stress, on quality and quantity of soybean seed protein and found that seed protein was significantly influenced by application of hydrogel.

Sendur *et al.* (2001) concluded that application of hydrogel significantly improved the root length and root dry weight. In tomato increased concentration of hydrogel application, significantly increased the root characteristics like root length, root volume, root fresh and dry weight at harvest due to well maintenance of water by hydrogel for a longer period (Meena *et al*., 2011). Similarly, in a pot culture study by Keshavarz *et al*. (2012) reported that incorporation of hydrogel @ 1.4 g pot^{-1} to the root zone of crop significantly improved the root dry weight in loamy sand soil, but the improvement was not significant in loamy soil.

2.1.3 Effect of hydrogel on yield and yield attributes of maize

Volkamar and Chang (1995) showed that grain yield of barley increased by 15 % and biomass by 23 % by hydrogel @ 1.87 g kg^{-1} soil, which was either due to more grains per spike or larger grains. Hydrogel applied @ 200 kg ha^{-1} in sandy soils of Iran showed that there was significant increase in the growth and yield parameters like number of branches per plant, seed yield, biomass yield, pod yield, and 100 seed weight of groundnut (Azarpour *et al*., 2013). Hydrogel applied @ 2.5 kg ha^{-1} considerably improved the dry matter, root growth, grain yield and WUE of both soybean and wheat in sequential cropping system (Narjary *et al*., 2015).

Mazen (2015) stated that drought stress reduced the grain weight and application hydrogel significantly increased the number of grains, number of rows and test weight. Kumari *et al*. (2017) also reported that hydrogel application @ 20 kg ha^{-1} resulted in significantly higher number of cob plant^{-1}, grain rows cob^{-1}, number of grains cob^{-1}, weight of grains cob^{-1}, test weight and shelling percentage compared to 0 and 15 kg ha^{-1} of hydrogel.

Magalhaes *et al.* (1987) observed that yield increase maize was low with low and medium dose of hydrogel application, while it was significant with high and very high dose of hydrogel application. The increase in yield was about 29.2 % and 27.8 % respectively. Lower dose (7.5 kg ha^{-1}) of superabsorbent polymer may be not sufficient to meet the water and nutrient needs of maize. Medium dose application (11.2 kg ha^{-1}) can brought some significant variation in crop performance. However, higher dose (15 kg ha^{-1}) will be an optimal dose for maize cultivation as it carries significant improvement in grain yield. Yangyuoru *et al.* (2006) also observed that the amendment of soil with natural and synthetic hydrogel increased maize yields by 36 %, and 31 % and increased bio mass yield by 92 % and 81 % respectively, than the control (without hydrogel).

2.1.4 Effect of hydrogel on soil physical properties

Maximum benefit of hydrogel on water storing was also depends on soil texture. Coarse textured soils with large pores hold very small amount of water than fine textured soils. Water holding capacity of hydrogel was maximum when hydrogel was incorporated in coarse textured soil than fine textured soil. Application of hydrogel reduced the bulk density of loamy and sandy soil, but there is small rise in the bulk density of clay soil. On the contrary, porosity of clay loam and sandy soils were increased with hydrogel application (Uz *et al.*, 2008).

Application of hydrogel will be a good management practice for maize production in soils with less water retaining capability where rain or irrigation water and fertilizer often percolate beneath the root zone in a short period leads to poor WUE (Dar *et al.*, 2017).

Drought is one of the most important problems to be solved in arid lands. Several studies have been focused on the efficacy of hydrogel uses in sandy soils and in soils of desert areas. Available soil water content and irrigation interval are enhanced by hydrogel application. As the dose of hydrogel was increased, the availability of water in the soil as well as the irrigation interval was also increased. Hydrogel prolongs the plant nutrient and water uptake by releasing the water slowly over a longer period. This reduced the water usage and improved the physical properties of soil. Moreover, the bio mass production was noticeably improved by efficient use of nutrients for plant growth and development (Gunes *et al*., 2016).

The soil amendment with hydrogel slowed down the rate of soil moisture loss and thus delayed the wilting of seedlings. Extending the period of PWP to 1.5, 2 and 5 days in sandy loam soil with increase in polymer concentration by 0.1, 0.2 and 0.3 % respectively were reported by (Akhter *et al*., 2004).

Hydrogel application improved the physical condition of soils like porosity, bulk density, water holding capacity, soil permeability, infiltration rate, etc. Improvement of soil porosity enhanced seed germination, seedling emergence rate, and root growth. It also improved biological/microbial activities in the soil that enhanced the aeration in root zone of plants. Increased water retaining ability in the root zone due to hydrogel application decreased the nutrient losses through leaching. Agricultural hydrogel can be used for all crops and all type of soils (Dar *et al*., 2017).

Hydrogel improved hydro physical and biological properties of the unproductive areas. Increased dose of hydrogel increased the maximum water content, PWP, water available for plants and drainage capacity and decreased bulk density. Hydrogel application also showed less rate of drying of plants and plant survival duration extended at the time of water stress (Baran *et al*., 2015).

Hydrogel application in winter wheat crop showed the positive effects on soil physical properties. Hydrogel applied @ 200 kg ha^{-1} significantly improved the water absorption capacity and presence of water stable hydrogel aggregates didn't cause any adverse effect on microbial community (Li *et al*., 2014).

2.1.5 Effect of hydrogel on soil moisture content

Hydrogel application preserved the water and increased the capability of soil to store moisture, ensured its availability, increased RLWC and finally increased the plant growth under moisture stress condition (Kramer, 1988).

Generally sandy soils are having less water holding capability. Application of hydrogel at 0.4 % increases the water holding capacity, maintains proper infiltration of water and reduces the deep percolation losses (Al-Darby, 1996).

A field experiment was conducted by Dass *et al.* (2013) stated that hydrogel applied @ 5 kg ha^{-1} significantly increased the soil water status at various depths like 0-15, 15-30 and 30-45 cm during all the crop growth stages of sorghum crop.

The application of high levels of Superab A200 @ 2, 4, 6 and 8 g kg^{-1} soil enhanced available water content approximately by 1.8, 2.2 and 3.2 fold in sandy loam, loamy and clay soils respectively as compared to that of the control and application of hydrogel increases the number of days to reach PWP. They also reported that the increase in saturated water content is in proportion to hydrogel application and the maximum value of saturated water content was with hydrogel @ 6 g kg^{-1} soil (Dar *et al.*, 2017).

Sandy soils were amended with hydrogel @ 0, 0.5, 1.0 and 2.0 % (w/w) and water retaining curve of sandy soil was found by using Richard's pressure plate apparatus. Hydrogel changed the soil water holding properties. Soil moisture at FC showed 400 % increase in the water holding capacity when amended with hydrogel than control and at PWP also showed similar results. There was an increase in the stored moisture content and saturated moisture content in available moisture tension range (0-15 bars) and available moisture in the soil enhanced 2.3 times than the control (Koupai *et al.*, 2008).

Hydrogel applications enhanced the moisture holding capability and provide a protection against the moisture stress. Drought stress leads to production of oxygen radicals, which results in increased lipid peroxidation and oxidative stress in the plant. Use of superabsorbent polymer could reserve different amount of water and increased the soil moisture retention capacity and finally decreased the drought stress (Nazarli *et al.*, 2010).

Abdulaziz and Al-Harbi (1996) stated that application of hydrogel was more effective when cucumber plants were grown under 25 % FC soil moisture level. Hydrogel application increases the irrigation interval by enhancing the available soil water in the root zone of the crop (El-Hady *et al.*, 2009).

2.1.6 Effect of hydrogel on WUE and nutrient use efficiency

Low moisture retaining capability, poor fertility and high percolation losses of soil moisture resulted in low crop productivity and reduced water and nutrient use efficiency in sandy soils (Rigas *et al.*, 1999; Sivapalan, 2006).

It was stated that, under moisture stress condition application of hydrogel increased the plants survival rate, WUE and DMP (Azzam, 1983). Hydrogel was used as a moisture holding substances in agriculture because when it is amended in soil, it holds high amount of moisture as well as nutrients and under moisture stress condition this preserved moisture and nutrients slowly released to the plants as per its requirements and finally enhanced the plant growth (Yazdani *et al.*, 2007).

Mikkelsen *et al.* (1993) observed that addition of hydrogel to the fertilizer solutions reduced nitrogen losses through leaching up to 45 % as compared to nitrogen fertilizer alone.

Magalhaes *et al.* (1987) found a decrease in leaching of nutrients like ammonical nitrogen, calcium, magnesium and potassium due to the presence of hydrogel. Increased N utilization was also observed by Dragicevic *et al.* (2011).

In sunflower, application of 100 % RDF (80:60:30 NPK kg ha^{-1}) along with hydrogel @ 2.5 kg ha^{-1} in furrows recorded maximum moisture content at various growth stages (Gaikwad *et al.*, 2017).

Results of the studies by Orzolek (1993), revealed the benefits of hydrogel application to soil. It increases the water holding capacity and soil nutrient reserves. Different enzymatic activities are the signs of microbial population in the soil. The enzymes like acid phosphatase, alkaline phosphatase, dehydrogenase, protease and urease were enhanced with hydrogel application in sandy soils (Borivoj *et al.*, 2006). According to De Mamann *et al.* (2017), there was increase in the nitrogen fertilizer use efficiency in wheat crop by using hydrogel. The maximum nitrogen use efficiency was found with 30 and 60 kg ha^{-1} of polymer, irrespective of the year and sequential cropping system.

Islam *et al.* (2011) reported that total N content at 0-15 cm soil depth was enhanced with reduced superabsorbent polymer dose, while an enormous enhancement of 19.3, 36.6 and 35.8 % respectively was observed with medium, high and very high hydrogel doses. Total nitrogen content at 15-30 cm depth was lower than surface level (0-15 cm) and it vary with different levels of hydrogel application. Available phosphorous content at 0-15 cm depth enhanced with medium, high and very high hydrogel doses by 20.5, 44.3 and 55.6 %, respectively and at 15-30 cm depth, it extended from 10.5 to 56.8%. Exchangeable K enhanced incredibly at 0-15 cm depth for high and very high polymer doses while the quantity at 15-30 cm did not change with superabsorbent polymer.

2.2 EFFECT OF MULCHING ON MAIZE

Agricultural sector consumed 60 % of the total water use in the world and was extremely sensitive to water shortages (Lin *et al.*, 2012). Rapid increase of world population, pollution of natural resources, global warming and climate change are increasing pressure on limited water resources and which caused a serious depletion of agricultural irrigation resources. Unavoidable global warming had been in progress with more frequent occurrences of extreme weather, which resulted in increasing water shortages (Kang *et al.*, 2017).

The arid and semi-arid regions of the world have particularly faced serious water scarcity problems due to limited rainfall and greater soil-moisture evaporation (Li *et al.*, 2000). As a result, farming practices are being developed in those regions aiming at conserving soil moisture. The practice of straw mulching was extensively used as a management practice to conserve soil moisture in the world (Ji and Unger, 2001). In recent years, with the improvement of the level of agricultural mechanization, about 90 % of the winter wheat is reaped by the combined harvester. Therefore, a large amount of winter wheat straw is left over in the field after harvest, which can be effectively utilized for mulching in the coming summer maize crop (Shen *et al.*, 2012).

Although, plastic mulch provided better yield (Mehan and Singh, 2015), in many cases, straw mulch has been recommended because of its local availability and convenience in application (Yin *et al.*, 2016).

The conservation of soil moisture is particularly significant for maize crop, as it is sensitive to water stress (Tolk *et al.*, 1999). In arid and semi-arid regions water stress is a major limiting factor of crop productivity (Tavakkoli and Oweis, 2004). In most cases, continuous drought during critical growth stages of maize along with reduced nutrient input leads to reduction in maize yield (Barron and Okwach, 2005).

Rice husks are the major by-products from rice mills. World annual paddy production now exceeds 300 billion kg from which about 60 billion kg of rice husk available annually and this provides an opportunity to use as a mulching material (Beagle, 1978).

Li *et al.* (2010) stated that various ridge and furrow methods with mulching may control the moisture intake rate at various growth stages.

2.2.1 Effect of mulching on growth and growth attributes of maize

Mulching is a unique management practice for enhancing WUE and weed control in the crop fields (Unger and Jones, 1981). Straw mulching might postpone the leaf senescence and advances the physiological productivity at grain filling stage. High leaf area at later stages of maize crop was due to mulching. However, increased canopy transpiration rate makes higher drought stress later within an irrigation cycle, mostly if the soil moisture storage capability is inadequate (Tolk *et al.*, 1999).

Initial maize growth was delayed by heavy mulching as a result of low soil temperature. However, maize grows taller and faster with heavy mulching successively due to improved soil moisture and ambient temperature which enhanced the root growth and development (Lal, 1974; Wicks *et al.*, 1994). There was an increase in the root length also observed by the application of mulch (Gill *et al.*, 1996).

Straw mulching obviously increased soil enzyme activities, to a certain level of dose only and there was no extended effect and had some adverse effect beyond 15, 000 kg ha^{-1}. Maize chlorophyll content was improved by straw mulching, and the maximum chlorophyll content was observed at straw mulching @ 12, 000 kg ha^{-1} (Zhang *et al.*, 2015).

2.2.2 Effect of mulching on LAI

Maize growth is dependent on the capability of the canopy to interrupt incoming radiation and translate it into dry matter (Gifford *et al.*, 1984). LAI is an important index to study the structure and function of a farmland ecosystem. Crop canopy structure and LAI affect biological and grain yield directly (Feng *et al.*, 2013). Significant increase in LAI with mulching was recorded by Li *et al.* (2013). Straw mulching @ 1.2 kg m^{-2} inhibited the maize LAI in the early growth stage and stimulated the LAI in the later growth stages of crop growth. However, no significant difference in LAI was observed between mulching and non-mulching treatments (Ma *et al.*, 2017).

2.2.3 Effect of mulching on dry matter production

Dry matter accumulation is closely related to crop economic output. The distribution rate of maize dry matter to stem, leaves and grains determines the dry matter utilization efficiency in the yield formation process. Therefore, it is important to observe the dry matter accumulation and distribution in maize (Karlen *et al.*, 1987). Straw mulching showed a significant effect on dry matter distribution in maize. At early growth stages it promoted dry matter accumulation into photosynthetic organs, which formed a larger photosynthetic source. At later stages it increases dry matter weight in ear head in order to enhance grain production. Since maize grains were formed after silking stage, but not all of the dry matter is accumulate to maize grains (Ning *et al.*, 2013), it is hypothesized that dry matter production and distribution is different in straw mulched and un mulched conditions, resulting in different grain yield. Therefore, it is very necessary to find out effective straw mulching measures to improve maize dry matter production and distribution to grains. Increased dry mater production with straw mulching was observed by Wang *et al.* (2015).

2.2.4 Effect of mulching on soil temperature

Reduction in the soil temperature due to straw mulching reduced the growth in early stages and enhanced in the middle and late stages (Chen *et al.*, 2004). The optimum temperature required during the flowering stage was 24 to 28 °C. While at grain filling stage the required temperature was 20 to 24 °C. If the temperature of less than 16 °C is prevailed continuously for longer time (more than 20 hours) between jointing stage and filling stage, the phenomenon of bald tip would be more (Zhao *et al.*, 2015).

Straw mulching reduced the soil temperature swing between the maximal and minimal and minimize the soil temperature flux between day and night (Gill *et al.*, 1996; Novak *et al.*, 2000; Chen *et al.*, 2004). Straw mulching decreased daily maximum soil temperature by 1.5 to 3.7 °C, though it enhanced the minimum daily soil temperature by 1.4 to 1.5 °C. Finally, mulching materials control soil temperature, which can augment or reduce crop yield. Similar temperature variation also observed by Li *et al.* (2008).

2.2.5 Effect of mulching on weed control

Organic mulching could not permit light to fall on top soil, thus decreasing the germination and growth of weeds, restricted by both the mechanical effect of mulching application (Hembry and Davies, 1994), and by the allopathic effect of mulches (Creamer *et al.*, 1996; Smeda and Weller, 1996).

In an experiment conducted by Moore *et al.* (1994) using triticale as a cover crop mulch, reduced the weed population compared to the bare soil. Khan and Parvej (2010) reported that rice straw mulch had significantly suppressed the weed growth and weed dry matter production was less than that of the dry matter obtained in control plot.

Sometimes, the natural mulches (straw, hay, husk and grass) are not good for weed control as they may contain seeds which become weeds (Boyhan *et al.*, 2006).

2.2.6 Effect of mulching on yield and yield attributes of maize

Application of straw mulch @ 12 t ha^{-1} improved yield by 8.8 % than control. The yield components like ear length, ear diameter, grains per ear and test weight were also significantly improved by straw mulch application. Maize yield and yield components were non-significant when straw mulching level was more than 12 t ha^{-1} (Zhang *et al.*, 2015).

Crop productivity can be significantly affected by even a lesser variation in soil moisture condition. Mulch could rise water output by decreasing evaporating losses from soil and supply that moisture to the plants for a longer period of time and subsequently enhance the yield or decrease the water input (Gill *et al.*, 1996; Tolk *et al.*, 1999; Wang *et al.*, 2011; Shen *et al.*, 2012; Stagnari *et al.*, 2014; Ma *et al.*, 2017; Yan *et al.*, 2017). The outcomes of research on maize yields in relation to straw mulch are still conflicting, including beneficial effects (Liu *et al*., 2010; Sharma *et al*., 2011; Wang *et al*., 2012; Liu *et al*., 2014; Li *et al*., 2015; Zhang *et al*., 2015), no clear effect (Govaerts *et al*., 2006; Huang *et al*., 2015) and harmful effects (Fabrizzi *et al*., 2005; Gao *et al*., 2009; Gupta *et al*., 2016), however all research were treated under similar amount of straw mulch @ 4.5 t ha^{-1}. Comparable useful outcomes were also observed in Mexico (Govaerts *et al*., 2006; Verhulst *et al*., 2011) and in India (Sharma *et al*., 2011; Lenka *et al*., 2013; Singh *et al*., 2016). The reason of the yield-improving effects of straw mulching may be due to stress in the crop root zone (Bansal *et al*., 1971), reduced loss of soil moisture (Chaudhary *et al*., 1985) and aeration (Sandhu *et al*., 1986), improved field microclimate (Li *et al*., 2008), increased soil organic matter (Mupangwa *et al*., 2013), soil carbon concentration (Kahlon *et al*., 2013) and humic substances (Szczepanek *et al*., 2016).

The greater number of grains cob^{-1} in the wheat straw mulched plots may be due to alterations in soil physical, chemical and biological features (Nill and Nill, 1993). Mulching level up to 6 t ha^{-1} improved the stover yield of maize. However, mulching levels of 6 and 8 t ha^{-1} improved the number of grains cob^{-1} than the control (Uwah and Iwo, 2011).

Gajri *et al*. (1994) reported that application of mulch improved corn grain yield in loamy sand from all 10 year's research. However, mulching declined yields of corn cultivated in sandy loam soil for few years and improved the yield in coming years compared with corn in control plot.

Mulching significantly improved the grain yield and dry matter production of other crops which are better for bearing of moisture stress, like sorghum, in adverse environment conditions, like high evaporation and less water availability (Tolk *et al*., 1999). Mulching significantly enhanced grain and dry matter production only when it is efficiently inhibited soil water evaporation so that maximum water was available for plants (Ma *et al*., 2017). Application of straw mulch @ 1.5 t ha^{-1} in wheat crop improved the yields. However, to confirm important beneficial effects on both soil and various crop physiological indicators, wheat straw @ 2.5 t ha^{-1} is crucial. While, it is indicated that wheat straw application @ 5 t ha^{-1} improved crop produce and soil properties.

Pooled analysis showed significantly more grains cob^{-1} and test weight with mulching than no mulching because of adequate soil moisture throughout growing season (Tolk *et al.*, 1999). Investigational confirmation (Singh *et al.*, 2011) and subjective indication from farmer field trials revealed that the existence of rice straw mulching preserves or enhances wheat crop yields and soil water. The main way to reduce soil evaporation might reserve moisture for succeeding usage by the plant for transpiration and it can lead to greater yields of crop, predominantly as an outcome of moisture conservation during the time of moisture scarcity period. Besides, it can decrease the demand for irrigation.

The precipitation at flowering stage and the low temperature caused by precipitation reduced the grain yield of maize. Straw mulching could keep heat and reduce the influence of temperature changes on the crops (Li *et al.*, 2008).

Previous researches had revealed that application of mulch could alter the crop moisture intake patterns i.e., it could reduce initial evaporation, enhance future transpiration and stimulate photosynthates accumulation. The three-years average corn yield for various treatments were in the order as maize straw > biodegradable film > plastic film > liquid film > control. Compared with un mulched treatment plots, the average corn yields with corn straw, biodegradable film, plastic film, were considerably improved by 13.0 %, 13.8 % and 15.0 % respectively. Furrows were mulched with plastic film, biodegradable film, or straw could prevent evaporation, increase soil water availability in the furrow, adjusted soil temperature and stimulated corn development, thus considerably enhanced corn yield and WUE (Li *et al.*, 2013).

Application of mulch increased the number of cobs $plant^{-1}$, cob length and diameter, tassel length, number of grain rows ear^{-1} and seeds row^{-1}, test weight, weight of rachis ear^{-1}, grain yield and greater harvest index (Khan and Parvej,

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2010). Uwah and Iwo (2011) assessed that the efficacy of organic mulch (Ganba grass) in five doses (0, 2, 4, 6, and 8 t ha^{-1}) on maize and revealed that greater plant height and number of leaves per plant were at 8 t ha^{-1} rate, although dry straw yield, weight of grains ear^{-1} and grain yield ha^{-1} maximum at 6 t ha^{-1} dose. Rajput *et al.* (2014) studied the effect of dust, green weed, kans grass, legume, paddy straw, subabul and wheat straw mulches @ 6 t ha^{-1} on corn under Guava based Agri-Horti System. The maximum yield was found with paddy straw mulching.

The use of crop residue mulches bargains the chance of considerably transforming the hydrothermal system of soil and, subsequently, attaining improved rooting, plant moisture status and enhanced maize yields (Bansal *et al.*, 1971; Chaudhary and Prihar, 1974; Gill *et al.*, 1996). Mulches protect the soils from wind and water erosions, which contribute directly to root stress and plant health (Chalker-Scott, 2007).

2.2.7 Effect of mulching on nutrient uptake of maize

The straw mulch application could bring advantage to corn yield and yield components because it might be efficiently progress soil nutrient availability, improves crop development (Fang *et al.*, 2011) and stimulate chemical properties of soil (Govaerts *et al.*, 2006). Greater test weight in zero tillage plus wheat straw may be due to correct water availability and recurrent availability of nutrients to maize crop. Additionally, mulch can enhance soil physical properties (Zamir *et al.*, 2013). Application of rice husk enhanced the chemical properties of soil and resulted in improved grain yield of corn. Rice husk improves the grain yield by preserving the nutrients through reduced leaching losses from the root zone (Njoku *et al.*, 2015).

Greater soil moisture in top soil and low diurnal top soil temperature deviation could be enhanced nutrient uptake, which will intensify the influence of mulching on growth and development. Sustaining residue on top soil hasn't constantly give increased yields. Yield decreases under great residue quantities, was owed partly to little N fertility (Unger, 1986).

Organic mulches may leave residual effects for about 4 to 5 years (Tilander, 1993). Crop residues mulch improves soil moisture reserves, enhance soil organic matter content and reutilize plant nutrients by decomposition, which directly influence crop yield by providing crop nutrients and indirectly by enhancing stability of aggregates and porosity of soil that improve soil quality and plant growth (Celik *et al*., 2004). The accumulation of nitrogen from straw mulches appeared to be 0.127 %. Mostly, the organic mulches are far slower than the chemical fertilizers in nutrient discharge to soil (Khan and Parvej, 2010).

Application of mulch is a desirable management practice which controls farm environment and improves crop yield through decreasing nutrient losses by run off (Smart and Bradford, 1999), leaching and ET (Liu *et al*., 2000), improving the soil organic matter concentration (Roldan *et al*., 2003) and modifying the soil temperature (Khan, 2010).

Mulch residue, besides regulating soil moisture and temperature, affects the changes of soil organic matter which could reduce the C: N ratio of plant residue by decomposing it (Chantigny, 2003).

Mulching treatments augment the total soil nitrogen when compare with bare soil, probably attributed to an increased nitrogen metabolism by nitrogen fixation that improve the protein production of the bacteria in nitrogen cycles. Improper application of mulches, on the other hand, creates an anaerobic environment under high precipitation situation, cause the nitrogen loss through denitrification. Mulching changes the structure of soil microbiology and diversity due to changes in soil moisture and soil temperature. Addition of organic matter to the soil from organic mulches is, therefore, very important (Acharya *et al*., 2005).

In the study of Smets *et al*. (2008), it was found that mulching materials on the soil surface improved soil hydrologic characteristics by enhancing soil physical and chemical properties. Organic mulches are very effective to increase soil quality and crop yield (Sinkeviciene *et al*., 2009). Too much organic mulch can lead to excess moisture, creating new problems such as pests, anaerobic conditions and

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rotting of the roots that can damage the plants. Continues application of straw mulches pollute the soil and reduce soil nitrogen because of its high C: N ratio (Kasirajan and Ngouajio, 2012). High carbon resources like straw or stalks when utilised for mulching, nitrogen from the soil might be utilised by microorganisms for decomposition of those resources. Therefore, nitrogen may not be available for plant utilization for certain period.

2.2.8 Effect of mulching on soil moisture and soil physical properties

Soil evaporation is not a valuable loss of moisture, apart from its effect in regulating vapour pressure deficit (VPD) (Leuning *et al.*, 1994). In coarse-textured soils the problem of moisture stress is severe due to low moisture holding capacity. The organic mulching reduced direct evaporation from the wet top soil (Ji and Unger, 2001).

Unger (1976) found that wheat straw mulch @ 4 t ha^{-1} notably decreases the evaporation from the wet soil. Soil evaporation can contribute 30 to 60 % of total crop water use from wheat crop (Cooper *et al.*, 1983), and it is a leading way for the movement of soil moisture to the atmosphere during early growth period (Yunusa *et al.*, 1993).

Shading is very effective at initial-stages of drying a wet top soil (Bond and Willis, 1970; Adams *et al.*, 1976). Mulching decreases evaporation of soil moisture mainly through covering top soil from sun (Li *et al.*, 2008). Finally, significant increase in soil-moisture storage under mulching because of reduction in soil evaporation (Singh *et al.*, 2015).

Scopel *et al.* (2004) reported that mulching was effective in reducing crop failure at field level due to increased water use efficiency. The high water content of soil increases root proliferation and enhances the availability of nutrients to crop roots (Sarkar, 2005). Straw mulching is known to play a significant role in reducing soil erosion, conserving soil moisture, restraining runoff and total sediment yield

(Zhang *et al.*, 2015), increasing WUE (Fernandez and Vega, 2016) and soil moisture (Fernandez *et al.*, 2016).

Mulching is a viable option for reducing the soil evaporative losses and increased crop yield through improvement in root growth due to conservation of soil moisture and reduced soil temperature (Chaudhary and Prihar, 1974; Tolk *et al.*, 1999). Mulching @ 8 t ha^{-1} showed the highest soil water content and lowest weed infestation than the control (Uwah and Iwo, 2011).

According to Mbagwu (1989), organic wastes application decreases soil apparent specific gravity and enhances total porosity of soil. Crop residue mulch application @ 4 and 6 t ha^{-1} improved chemical and physical properties of the soil and finally increased grain yield of the crop (Bhatt *et al.*, 2004; Khurshid *et al.*, 2006). Mulching offers an improved soil environment, controls soil temperature, enhances soil porosity and water infiltration rate at severe rain and maintains runoff and erosion besides it suppress weeds development (Anikwe *et al.*, 2007; Glab and Kulig, 2008). Besides preserving water and preventing erosion, mulching also enhanced the soil flora and fauna, suppress weeds growth and maintain maximum crop productivity (Essien *et al.*, 2009). The findings proved that rice husk upgraded soil physical properties which improves the corn grain yield. Porosity significantly changes moisture circulation and air exchange in soil (Uguru *et al.*, 2015).

Wang *et al.* (2011) reported that the amount of soil moisture in surface layers (0 to 20 cm and 20 to 40 cm) varied mostly among all the treatments at different stages with higher soil moisture in ridges using wheat straw mulch. Ma *et al.* (2012) indicated that below field capacity, a greater soil moisture content resulted in a greater rate of emergence in maize. Soil drought delays the period of emergence and decreases the emergence rate of maize. Therefore, in the early growth stages of maize, soil moisture is a very important factor in determining plant population and stable grain yield. At flowering stage, soil water content was far greater in straw mulched plots than control plots. Soil moisture content enhanced as straw mulch rate increases. LAI also increased by the straw mulch application, so that there is an increase in the transpiration ratio and phase evapotranspiration. However, at harvest stage the soil moisture content was lesser in mulched plots than control plots (Shen *et al*., 2012).

According to Mulumba and Lal (2008) the increased maize yield in mulching is an effect of decreased soil moisture evaporation, reduced surface runoff and increased infiltration. The amount of soil moisture conservation under different mulching materials differs in different soil types and climatic conditions. In general, the mulching treatments store higher soil moisture compared to the bare soil (no mulch) (Chakraborty *et al*., 2008; Zhao *et al*., 2014). Soil moisture enhances nutrients releasing rate and allows the transportation (Kiboi *et al*., 2017).

Application of straw mulching at 4-6 t ha^{-1} was found effective in improving soil physical condition, including protection of the topsoil in tropical environments (Lal, 1974). The efficiency of different mulching material with reference to soil moisture was in the order as rice straw>water hyacinth>rice husk>ash>control. This may be due to decreased evaporation (Cui *et al*., 1998), enhanced hydraulic conductivity, water holding capacity (Xu *et al*., 1988), plant transpiration (Shekour *et al*., 1987) and transmissivity (Mbagwu, 1990).

Khan *et al*. (1988) found that mulching with rice straw to be more effective than plastic mulch. Begum *et al*. (2001) reported that the highest soil-moisture storage was obtained with straw mulch among different mulch treatments. Liu *et al*. (2010) reported that straw mulch @ 6 t ha^{-1} saved 30 mm soil moisture storage in soil profile of top 200 cm.

Khan and Parvej (2010) stated that rice straw residual mulch has no influence on physical properties of the soil. However, it preserves highest soil moisture throughout the growing period of crop than other mulches. Ashrafuzzaman *et al*. (2011), on the other hand, did not find any significant difference in soil-moisture contents among the various mulch treatments, but, they always obtained greater soil moisture content under mulch treatments than the bare soil.

Bacterial populations increase under organic mulches due to different chemical compositions and decomposition rates of organic materials (Mukherjee *et al.*, 1991). Mulching also enhances the soil biotic activities of earthworms (Lal, 1998) and other soil fauna that improve the soil structure and quality (Doring *et al.*, 2005).

Anikwe *et al.* (2000) stated that rice husk @ 4.5 t ha^{-1} could be utilised as a substance to change the physical properties of clayey soil. It improves the total porosity, saturated hydraulic conductivity, decreased bulk density and infiltration resistance and finally improved moisture transmissivity, soil aeration and microbial activity of clay soil. The mulches reduce deterioration of soil quality by preventing runoff and reducing soil loss that improves soil aeration, soil structure, organic matter content and physical properties of the soil. The effect of mulching on soil bulk density varies depending on type and properties of the soil, type of mulch, climate and land use (Mulumba and Lal, 2008). Application of compost mulch decreases the surface runoff at and after precipitation, enhances infiltration and decreases soil loss (Bakr *et al.*, 2015).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

An investigation entitled "Effect of hydrogel and mulching on maize (*Zea mays* L.) in sandy soil" was carried out at College of Agriculture, Padannakkad during 2016-18 to study the effect of hydrogel (super absorbent polymer) and mulching on soil moisture status, growth and yield of maize in sandy soil.

Relevant details about materials used, methods adopted and practices employed at the time of research are described in this chapter.

3.1 MATERIALS

3.1.1 Experimental site

The field experiment was conducted at College of Agriculture, Padannakkad, Kerala Agricultural University (KAU), Kerala. It is situated at 12° 20' 30" °N latitude and 75° 04' 15" °E longitude at an altitude of 20 m above the mean sea level. This area enjoys a typical warm humid tropical climate.

3.1.2 Soil type

The soil of the experimental site is sandy in texture and the physical and chemical characteristics of the soil are given in the Table 1.

3.1.3 Climate

The weather parameters were recorded for the standard weeks at the time of crop period and are furnished in Appendix I and Fig. 1. The abstract of weather data is given in Table 2.

3.1.4 Season

The field study was conducted in *rabi* season of the year 2017-18. The crop was sown on 8th November, 2017 and harvested on 25th February, 2018.

Table 1. The physical and chemical characteristics of the soil

Parameters	Content	Method used
pH	6.60	pH meter (Jackson, 1958)
EC (dS m^{-1})	0.14	Conductivity meter (Jackson,1958)
Organic carbon (%) Organic matter (%)	0.54 0.93	Chromic acid wet digestion method (Walkley and Black, 1934)
Bulk density (g cc^{-1})	1.47	Undisturbed core sample (Black *et al.*, 1965)
Particle density (g cc^{-1})	2.50	Pycnometer method (Black *et al.*, 1965)
Porosity (%)	41.20	Black *et al.* (1965)
Soil moisture content (%) at FC PWP	 7.72 3.21	Gravimetric method (Reynolds, 1970)
Hydrogel expansion on weight basis (grams)	131.36 times	-------
Textural analysis Sand (%) Silt (%) Clay (%)	 87.93 7.5 4.57	International pipette method (Robinson, 1922)
Available N (kg ha^{-1})	112.90	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	52.58	Bray extraction and photoelectric colorimetry (Jackson, 1958)
Available K_2O (kg ha^{-1})	178	Ammonium acetate method (Jackson, 1973)

Table 2. The abstract of weather data during the experimental period

Weather element	Range	Mean
Maximum temperature (°C)	30.64 – 32.33	31.48
Minimum temperature (°C)	17.75 – 22.36	20.05
Rainfall (mm)	------	30.5
Relative humidity (%)	71.81 – 82.29	77.05
Average daily evaporation (mm)	2.91 – 4.51	3.71

3.1.5 Crop variety

The variety used was DHM 117, a medium duration hybrid variety of about 90-105 days, released from Acharya N. G. Ranga Agricultural University, Hyderabad. The grains are orange in colour with an average yield of 7.5 t ha^{-1}. It is tolerant to stem borer and wilt disease. The stover is used as a livestock feed as it contains some moisture at the time of harvest. It is suitable under zero tillage system and its stem is tough enough to impart resistance to lodging.

3.1.6 Hydrogel (super absorbent polymer)

The hydrogel used in this experiment was PUSA Hydrogel, which is released from division of Agricultural chemicals, Indian Agricultural Research Institute, New Delhi. Hydrogel (super absorbent polymer), a water retaining, cross linked poly acrylamide which can absorb and retain water at least 400 times than its original weight and progressively discharges the same. It reduces irrigation and fertilizer requirements of crops and it also improves physical properties of soils and soil less media. It is moderately bio-degradable in soil by both ionic and microbial action and finally it is converted to ammonia and CO_2. Biodegradable hydrogels contain to prepare the hydrogels. The labile bonds can be broken under

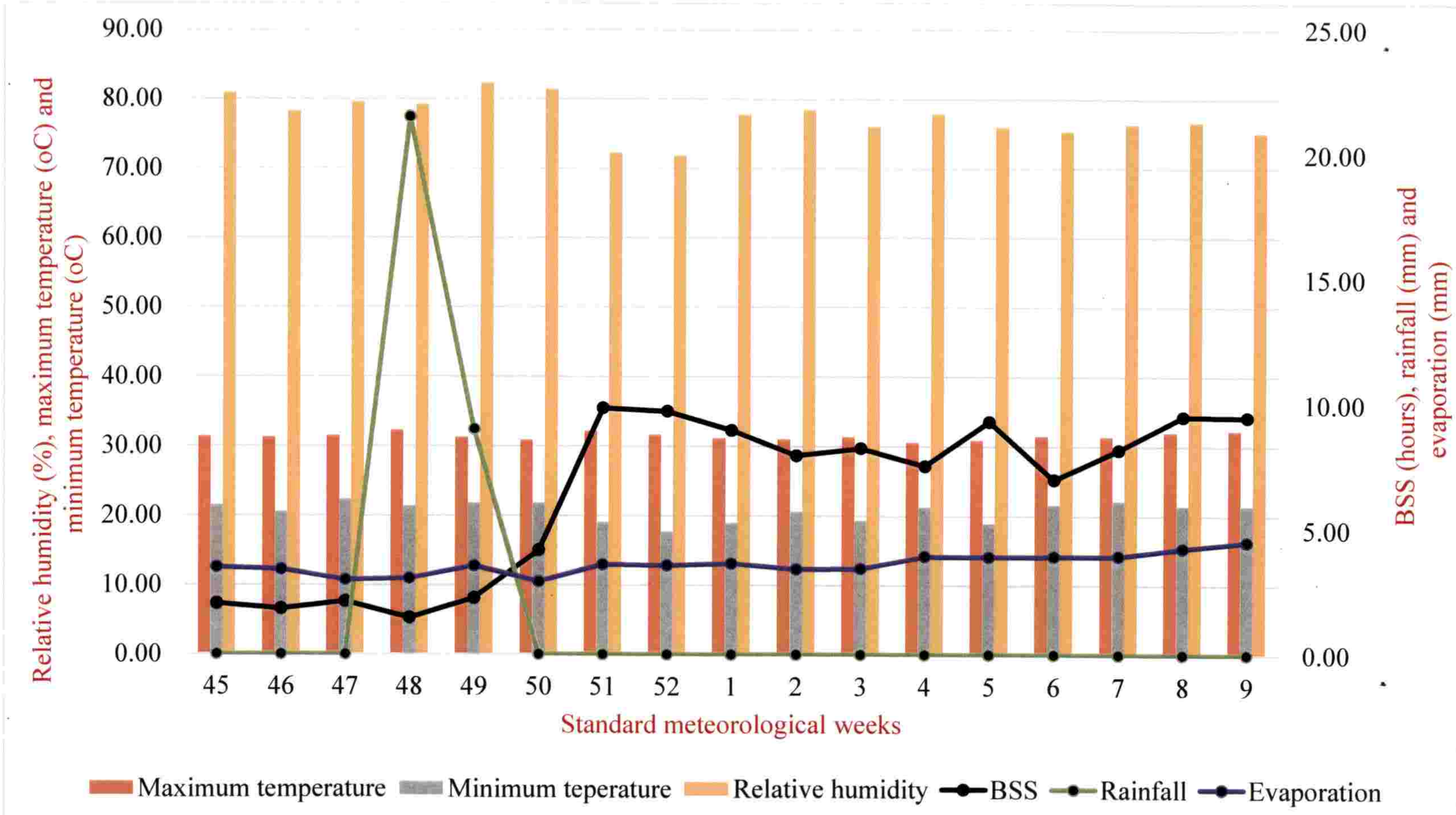

Fig. 1. Weather parameters during the crop season in standard weeks

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physiological conditions either enzymatically or chemically over a long period of time. End-products after degradation were carbon dioxide, water and ammonia. Acrylamide, a monomer used for hydrogel preparation can be 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 used as backbone. Acrylamide residue was also not noticed in crop products which were grown with application of hydrogel. So these hydrogels are safer to the environment (Ekabafe *et al*., 2011). The half-life of hydrogels in general is in the range of 5-7 years and can withstand high temperatures (40 to 50 ^{0}C) and are more suitable to semi-arid and arid regions (Dar *et al*., 2017).

3.1.7 Source of seed material

Seeds of DHM 117 were purchased from Professor Jayashanker Telangana State Agricultural University, Hyderabad.

3.1.8 Source of Hydrogel

Pusa hydrogel used in this experiment was purchased from Carborundum Universal Limited and supplied by Kanakadhara Agriculture Innovations Pvt. Ltd.

3.1.9 Manures and Fertilizers

Well decomposed FYM containing 0.5 % N, 0.2 % P_2O_5 and 0.5 % K_2O was used for this experiment. The fertilizers used for the experiment were urea containing 46 % N, complex fertilizer ammonium phosphate sulphate 20:20:0:13 contains 20 % N and 20 % P_2O_5 and 13 % sulphur and muriate of potash containing 60 % K_2O.

3.2 DESIGN AND LAYOUT

Design : Factorial RBD ($3^2 + 1$)

Treatments : 3 x 3 + 1 = 10

Factor A – hydrogel (3 levels)

H_1 – 1.25 kg ha^{-1}

H_2 – 2.5 kg ha^{-1}

H_3 – 3.75 kg ha^{-1}

Factor B – Mulch (3 types)

M_1 – Rice straw

M_2 – Rice husk

M_3 – Coirpith compost

Control (KAU Package of Practices recommendations, 2016)

Season : *Rabi* season 2017-18

Replications : 3

Gross plot size : 4 m x 4.2 m

Net plot size : 3.6 m x 3.0 m

Spacing : 60 cm x 20 cm

3.2.1 Treatment combinations:

T_1 : 1.25 kg ha^{-1} hydrogel + Rice straw

T_2 : 1.25 kg ha^{-1} hydrogel + Rice husk

T_3 : 1.25 kg ha^{-1} hydrogel + Coirpith compost

T_4 : 2.5 kg ha^{-1} hydrogel + Rice straw

T_5 : 2.5 kg ha^{-1} hydrogel + Rice husk

T_6 : 2.5 kg ha^{-1} hydrogel + Coirpith compost

T_7 : 3.75 kg ha^{-1} hydrogel + Rice straw

T_8 : 3.75 kg ha^{-1} hydrogel + Rice husk

T_9 : 3.75 kg ha^{-1} hydrogel + Coirpith compost

T_{10} : Control (KAU Package of Practices)

Rice straw and rice husk @ 5 t ha^{-1} and coir pith compost @ 2.5 t ha^{-1} were used for the experiment.

3.3 FIELD EXPERIMENT

3.3.1 Land preparation

The land was ploughed uniformly, levelled and the stubbles were removed and experimental plots were laid out as per the technical programme. Soil samples were collected from the experimental plots for basic analysis. Individual plots were levelled uniformly before sowing.

3.3.2 Application of hydrogel

Before application of hydrogel furrows were made at 60 cm apart to a depth of 10-15 cm. Hydrogel was mixed with the dried sand and applied in the furrows uniformly. After application of hydrogel furrows were covered with top soil and seeds were sown on those furrow lines.

3.3.3 Seeds and sowing

Maize variety, DHM 117 was sown @ 20 kg ha^{-1} at a spacing of 60 cm x 20 cm.

3.3.4 Application of manures and fertilizers

Farmyard manure was applied uniformly to all the plots @ 25 t ha^{-1} as basal dose and well mixed with top soil. Fertilizers were applied as per KAU package of

N

R_1	R_2	R_3
T_2	T_4	T_6
T_9	T_8	T_1
T_1	T_9	T_4
T_4	T_7	T_2
T_8	T_3	T_9
T_6	T_2	T_{10}
T_{10}	T_5	T_3
T_3	T_{10}	T_8
T_5	T_6	T_7
T_7	T_1	T_5

3 m

3.6 m

Fig.2. Layout plan of the experiment

practices recommendations (2016). Nitrogen was applied in three equal doses, first as basal dose, second at knee high stage or grand growth stage and third at tasselling stage. Full dose of P and half dose of potassium was applied as basal and the remaining half dose of potassium was applied at tasselling stage along with N.

3.3.5 After cultivation

Gap filling was done one week after sowing and thinning was done 15 DAS and one hand weeding was carried out along with thinning. Two earthing up operations were also done, first at 25 DAS and second at 45 DAS at the time of fertilizer application.

3.3.6 Water management

Irrigation was given at 75 per cent of pan evaporation at 5 days interval in the initial stages and later on at an interval of 4 days.

3.3.7 Plant protection

Flubendiamide (Fame) @ 0.2 ml lit^{-1} of water was sprayed to control leaf roller below Economic Threshold Level at 25 DAS. Thiamethoxam (Thioxam) @ 0.3 grams lit^{-1} of water was sprayed at tasseling stage for controlling aphid attack. Flubendiamide (Tacumi) @ 0.3 grams lit^{-1} of water was sprayed at milky stage to control cob worm attack.

3.3.8 Plant sampling

Plant samples were collected at 30, 60 and 90 DAS and at harvesting stage for biometric observations and chemical analysis.

3.3.9 Harvesting

Maize cobs were harvested at 110 DAS when the grains had an attractive dark orange colour, characteristics of the particular variety.

3.4 OBSERVATIONS

3.4.1 Observations on growth and growth attributes

3.4.1.1 Plant height

Mean plant height of five randomly chosen plants in each plot was recorded at 30, 60, 90 DAS and at harvest stage and expressed in cm.

3.4.1.2 Number of leaves

The number of leaves was recorded by taking mean values of leaf numbers from five plants from each plot at 30, 60, 90 DAS and at harvest stage.

3.4.1.3 Leaf area

The area of the single leaf was measured by using portable leaf area meter and the total leaf area of the plant was calculated on area: weight basis at 30, 60, 90 DAS and at harvest stage and expressed in cm^2.

3.4.1.4 Leaf Area Index

Leaf Area Index is a measure of extent of crop canopy covering the land. Three plants from each plot were taken at 30, 60, 90 DAS and at harvest stage. The leaves were separated. The LAI was worked out by using the formula given by (Watson, 1952) as

$$\text{LAI} = \frac{\text{Leaf area occupied by the plant}}{\text{Land area occupied by the plant}}$$

3.4.1.5 Dry matter production

Three plants were uprooted from the sampling area earmarked for destructive sampling and recorded the total dry matter production at 30, 60, 90 DAS and at harvest stage. The samples were dried in a hot air oven at 60 °C till they attained a constant weight. Total dry matter accumulation was expressed in g plant^{-1}.

3.4.1.6 Relative Leaf Water Content (RLWC)

The method proposed by Weatherley (1950) which was later modified by Slatyer and Barrs (1965) was used to estimate RLWC at 30, 60 and 90 DAS and it was expressed in %. The formula is

$$RLWC = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

3.4.2 Observations on yield and yield attributes of maize

3.4.2.1 Number of cobs plant^{-1}

Observation on number of cobs plant^{-1} was recorded from five maize plants in each plot at harvesting stage and their mean values were calculated and recorded.

3.4.2.2 Number of grain rows cob^{-1}

Five cobs were taken from each plot for recording the number of rows of grains. Number of rows in each cob was counted and the average number of rows was recorded for each treatment.

3.4.2.3 No. of grains cob^{-1}

Total number of grains cob^{-1} was calculated from the total number of rows of grain cob^{-1} and total number of grains per row of five cobs and mean value were taken.

3.4.2.4 Length of cob

Mean values of five cobs from the selected plants from each plot were taken and length of cobs were recorded.

3.4.2.5 Girth of cob

Girth of each cob was taken by measuring the circumference of the cob at three regular intervals at the top, bottom and central portions. From the means of these three readings, the mean girth of each cob was obtained.

3.4.2.6 Test weight (100 grains)

Hundred grains weight was taken for each plot and it was expressed in gram.

3.4.2.7 Grain yield

At maturity stage, maize cobs were harvested from each net plot area. The harvested cobs were air dried, shelled, cleaned and weighed. Grain yield ha^{-1} was computed from yield per net plot and expressed in t ha^{-1}.

3.4.2.8 Cob yield

Before shelling of cobs, cob yield ha^{-1} was computed from yield per net plot and expressed in t ha^{-1}.

3.4.2.9 Stover yield

After the cobs were picked up, the stover left in the field was also harvested by sickle. They were put into bundles separately for each treatment. The bundles of each plot were dried and weighed separately. Stover yield ha^{-1} was computed from that yield per net plot, which was expressed in t ha^{-1}.

3.4.2.10 Harvest index

It is ratio of economic yield of maize to that of biological yield.

3.4.3 Observations on Plant analysis

3.4.3.1 Nutrient content of plant (N, P, K)

At harvest stage plant samples were collected and analysed it for N, P, K nutrients content using standard procedures as given in the following table.

Table 3. Methods used to analyse N, P, K nutrients content of plant

S. No.	Parameter	Method	Reference
1.	Total N	Modified kjeldhal digestion method	Jackson (1958)
2.	Total P	Vanadomolybdate yellow colour method	Piper (1966)
3.	Total K	Flame photometry	Jackson (1958)

3.4.3.2 Nutrient uptake

Uptake of N, P and K nutrients were estimated by multiplying nutrient content of the sample with respective dry weight of plant samples and expressed in kg ha^{-1}.

$$\text{Nutritive uptake} = \frac{\text{Percentage of nutrient X Total dry matter production (kg ha}^{-1}\text{)}}{100}$$

3.4.4 Observations on soil analysis

3.4.4.1 Moisture content of soil

Moisture content of soil is estimated by gravimetric method of soil moisture estimation. Soil samples were collected at 15 cm and 30 cm depths at sowing, 30, 60, 90 DAS and at harvesting stage for estimating moisture content of the soil.

3.4.4.2 Physical properties of the soil

Physical properties of the soil like bulk density and porosity were estimated before the start of the experiment and at harvest.

3.4.4.3 Nutrient status of soil

Before sowing and at harvest of the crop soil samples were collected from each plot at 0-20 cm depth. Available N, P_2O_5 and K_2O of soil were estimated before and after the experiment and were expressed in kg ha^{-1}. Methods adopted for analysis are indicated in Table 1.

3.4.5 Economics

The input prices and the maize crop market price prevailing at the time of harvest were taken to calculate the cost of cultivation and economics.

3.4.5.1 Gross return

Gross return was calculated on the basis of grain and straw yield and their existing market price. The following formula is used for calculation of gross return.

$$\text{Gross return } (₹\text{ ha}^{-1}) = \text{Grain yield (t ha}^{-1}) \text{ x Market price } (₹\text{ t}^{-1}) + \text{Stover yield (t ha}^{-1}) \text{ x Market price } (₹\text{ t}^{-1})$$

3.4.5.2 Net return

Net return is the income obtained after subtraction of cost of cultivation (Rs. ha^{-1}) from gross income (₹ ha^{-1}).

$$\text{Net return } (₹\text{ ha}^{-1}) = \text{Gross return } (₹\text{ ha}^{-1}) - \text{Cost of cultivation } (₹\text{ ha}^{-1})$$

3.4.5.3 Benefit: Cost Ratio (BCR)

It is the ratio of gross return (₹ ha^{-1}) to the cost of cultivation (₹ ha^{-1})

$$\text{BCR} = \frac{\text{Gross return } (₹\text{ ha}^{-1})}{\text{Cost of cultivation } (₹\text{ ha}^{-1})}$$

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3.4.6 Statistical analysis

The data obtained from the experiment was analysed statistically by using procedure given by Rangaswamy (1995). The level of significance used in 'F' and 't' tests was P=0.05.

RESULTS

4. RESULTS

The project entitled "Effect of hydrogel and mulching on maize (*Zea mays* L.) in sandy soil" was conducted at the college of Agriculture, Padannakkad during *rabi* season of 2017-2018. The experiment was aimed to study the effect of hydrogel and mulching on soil moisture status, growth and yield of maize in sandy soil so that maize can be proposed as an alternate crop in summer rice follows of northern parts of Kerala. The data on growth and growth attributes, yield and yield attributes, plant analysis, soil analysis and economics of cultivation are analysed statistically and results are presented here under.

4.1 GROWTH AND GROWTH ATTRIBUTES

4.1.1 Plant height

The data pertained in Table 4 showed that height of plant was significantly influenced by levels of hydrogel and types of mulch. At 30 DAS, the maximum plant height was recorded in treatments where hydrogel was applied @ 2.5 kg ha^{-1} (38.49 cm) which was significantly superior to other levels of hydrogel. Effect of hydrogel on plant height was not significant at 60 DAS. Among the types of mulch, rice straw mulch @ 5 t ha^{-1} recorded maximum plant height at 30 DAS (39.76 cm) and 60 DAS (206.90 cm) and was significantly superior to other types of mulch.

Interactions between hydrogel and mulch showed significant results on plant height at 30 DAS and it was non-significant at 60 DAS. At 30 DAS maximum plant height was recorded with interaction H_2M_1 (41.16 cm) which was on par with H_1M_1 and significantly superior to other combinations.

Comparing the plant height of control with other treatments, at 30 and 60 DAS it was found that plant height was minimum in control plot. Plant height in all the treatments was significantly superior to control at 30 and 60 DAS. No significant difference was observed in plant height after 60 DAS.

4.1.2 Number of leaves

The results pertaining the effect of hydrogel and mulching on number of leaves plant^{-1} at 30, 60 and 90 DAS were presented in Table 4. The number of leaves was not affected significantly by levels of hydrogel at 30, 60 and 90 DAS.

Among the types of mulch, the observation on number of leaves was significant at 60 and 90 DAS only. At 60 and 90 DAS the maximum number of leaves was noticed in rice straw mulch @ 5 t ha^{-1} (14.31 and 10.71 respectively). Combined effect of levels of hydrogel and types of mulch was not significant at 30, 60 and 90 DAS.

When treatment effects were compared with control, total number of leaves was found significant at 30 and 90 DAS. Control had lower number of leaves than all other treatments and its combinations.

4.1.3 Leaf area

Data on leaf area plant^{-1} at different growth stages of maize is presented in Table 4. It was observed that leaf area was significantly influenced by different levels of hydrogel at 30, 60 and 90 DAS. Leaf area was maximum when hydrogel was applied @ 3.75 kg ha^{-1} at all stages of observations (1196 cm^2, 3988 cm^2 and 3572 cm^2 respectively) and was significantly superior to other levels of hydrogel.

Leaf area was significantly influenced by types of mulch at 30, 60 and 90 DAS. The maximum leaf area was noticed with rice straw mulch @ 5 t ha^{-1} at all the stages under observations (1327 cm^2, 4097 cm^2 and 4020 cm^2 respectively) which was significantly superior to rice husk and coirpith compost mulch.

With regard to interactions between levels of hydrogel and types of mulch it showed a significant influence on leaf area at 30, 60 and 90 DAS. At 30, 60 and 90 DAS, maximum leaf area was recorded with interaction H_3M_1 (1454 cm^2, 4165 cm^2, 4071 cm^2 respectively) and was on par with H_2M_1 at 60 and 90 DAS and with H_1M_1 at 90 DAS.

Table 4. Effect of hydrogel and mulching on plant height, number of leaves and leaf area

Treatment	Plant height (cm)		Number of leaves $plant^{-1}$			Leaf area $plant^{-1}$ (cm^2)		
Levels of hydrogel	30 DAS	60 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
H_1	36.61	195.89	9.04	14.02	10.27	1105	3834	3435
H_2	38.49	198.79	9.00	13.84	10.13	1073	3899	3472
H_3	37.13	198.85	8.89	14.13	10.09	1196	3988	3572
SEm (±)	0.451	3.575	0.249	0.184	0.292	23.82	30.47	43.57
CD (0.05)	0.948	NS	NS	NS	NS	50.05	64.01	91.54
Types of mulch								
M_1	39.76	206.90	9.18	14.31	10.71	1327	4098	4020
M_2	35.44	188.54	8.73	13.84	9.80	990	3767	3058
M_3	37.03	198.09	9.02	13.84	9.98	1058	3856	3401
SEm (±)	0.451	3.575	0.249	0.184	0.292	23.82	30.47	43.57
CD (0.05)	0.948	7.511	NS	0.387	0.614	50.05	64.01	91.54
Interactions								
H_1M_1	40.27	203.04	9.27	14.07	10.33	1227	4006	3971
H_1M_2	34.25	186.19	8.60	13.87	10.13	1039	3614	3059
H_1M_3	35.31	198.45	9.27	14.13	10.33	1048	3881	3274
H_2M_1	41.16	209.19	9.40	14.33	11.20	1300	4122	4019
H_2M_2	34.95	190.93	8.80	13.87	9.73	951	3758	3074
H_2M_3	39.35	196.25	8.80	13.33	9.47	968	3817	3324
H_3M_1	37.84	208.46	8.87	14.53	10.60	1454	4165	4071
H_3M_2	37.11	188.51	8.80	13.80	9.53	978	3930	3040
H_3M_3	36.43	199.57	9.00	14.07	10.13	1157	3870	3605
SEm (±)	0.782	6.192	0.432	0.319	0.506	41.26	52.77	75.47
CD (0.05)	1.643	NS	NS	NS	NS	86.68	110.87	158.56
Control *vs* other treatments								
Control	31.93	181.98	8.20	13.60	9.07	86	3409	2909
SEm (±)	0.583	4.615	0.322	0.238	0.377	30.75	39.33	56.25
CD (0.05)	1.224	9.697	0.676	NS	0.792	64.61	82.64	118.18

Note: H_1 - hydrogel @ 1.25 kg ha^{-1}, H_2 - hydrogel @ 2.5 kg ha^{-1},

H_3 - hydrogel @ 3.75 kg ha^{-1}, M_1 - rice straw mulch @ 5 t ha^{-1},

M_2 - rice husk mulch @ 5 t ha^{-1}, M_3 - coirpith compost mulch @ 2.5 t ha^{-1}.

When compared with control significant difference was observed between control and other treatments. Control recorded significantly lower leaf area at 30, 60 and 90 DAS. At harvest stage leaf area was not recorded as the entire plant was dried.

4.1.4 Leaf Area Index (LAI)

Data on LAI at different growth stages of maize is presented in Table 5. It was observed that LAI was significantly influenced by different levels of hydrogel at 30, 60 and 90 DAS. LAI was higher when hydrogel was applied @ 3.75 kg ha^{-1} at all stages of observations (1.00, 3.32 and 2.98 respectively) and was significantly superior to other levels of hydrogel.

LAI was significantly influenced by types of mulch at 30, 60 and 90 DAS. The maximum LAI was noticed with rice straw mulch @ 5 t ha^{-1} at all the stages under observations (1.11, 3.41 and 3.35 respectively) which was significantly superior to rice husk and coirpith compost mulch.

With regard to interactions between levels of hydrogel and types of mulch significant influence on LAI was observed at 30, 60 and 90 DAS. At 30, 60, 90 DAS, maximum LAI was recorded with interaction H_3M_1 (1.21, 3.47 and 3.39 respectively) and was on par with H_2M_1 at 60 and 90 DAS and with H_1M_1 at 90 DAS. Control recorded significantly lower LAI at 30, 60 and 90 DAS.

4.1.5 Dry matter production

The data regarding the effect of hydrogel and mulching on dry matter production plant^{-1} at 30, 60, 90 DAS and at harvest stage are presented in Table 5.

The dry matter production revealed significant difference among the levels of hydrogel at 30, 60 DAS and at harvest stage while it was non-significant at 90 DAS. Maximum dry matter production at 30 and 60 DAS was observed in hydrogel applied @ 3.75 kg ha^{-1} (7.37 and 78.07 g plant^{-1} respectively).

Table 5. Effect of hydrogel and mulching on LAI and DMP

Treatment	LAI			DMP plant^{-1} (g plant^{-1})				
Levels of hydrogel	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	At harvest	% increase over control at harvest
H_1	0.92	3.19	2.86	6.86	67.87	205.56	267.49	26.31
H_2	0.89	3.25	2.89	6.83	72.06	207.82	297.06	40.27
H_3	1.00	3.32	2.98	7.37	78.07	208.01	278.13	31.34
SEm (±)	0.020	0.025	0.036	0.222	0.767	3.261	6.401	
CD (0.05)	0.042	0.053	0.076	0.466	1.612	NS	13.449	
Types of mulch								
M_1	1.11	3.41	3.35	8.39	86.12	239.10	303.42	43.28
M_2	0.82	3.14	2.55	5.98	65.75	185.03	271.58	28.24
M_3	0.88	3.21	2.83	6.70	66.12	197.25	267.68	26.40
SEm (±)	0.020	0.025	0.036	0.222	0.767	3.261	6.401	
CD (0.05)	0.042	0.053	0.076	0.466	1.612	6.851	13.449	
Interactions								
H_1M_1	1.02	3.34	3.31	8.20	81.09	235.48	285.64	34.88
H_1M_2	0.87	3.01	2.55	6.03	61.02	188.65	245.19	15.78
H_1M_3	0.87	3.23	2.73	6.36	61.51	192.54	271.65	28.28
H_2M_1	1.08	3.43	3.35	7.01	82.14	243.18	320.58	51.38
H_2M_2	0.79	3.13	2.56	6.88	67.97	173.87	302.45	42.82
H_2M_3	0.81	3.18	2.77	6.61	66.05	206.39	268.16	26.63
H_3M_1	1.21	3.47	3.39	9.97	95.14	238.63	304.06	43.58
H_3M_2	0.82	3.27	2.53	5.02	68.27	192.57	267.11	26.13
H_3M_3	0.96	3.22	3.00	7.12	70.79	192.82	263.23	24.30
SEm (±)	0.034	0.044	0.063	0.384	1.329	5.648	11.087	
CD (0.05)	0.072	0.092	0.132	0.807	2.792	11.866	23.294	
Control *vs* other treatments								
Control	0.72	2.84	2.42	4.46	57.50	142.15	211.77	
SEm (±)	0.026	0.033	0.047	0.286	0.990	4.210	8.264	
CD (0.05)	0.054	0.069	0.098	0.601	2.081	8.844	17.362	

Note: H_1 - hydrogel @ 1.25 kg ha^{-1}, H_2 - hydrogel @ 2.5 kg ha^{-1},

H_3 - hydrogel @ 3.75 kg ha^{-1}, M_1 - rice straw mulch @ 5 t ha^{-1},

M_2 - rice husk mulch @ 5 t ha^{-1}, M_3 - coirpith compost mulch @ 2.5 t ha^{-1}.

But at harvest stage maximum dry matter production was recorded by the treatment where hydrogel was applied @ 2.5 kg ha^{-1} (297.06 g plant^{-1}) which was on par with hydrogel level @ 3.75 kg ha^{-1}. All the treatments and their interactions were significantly superior over control.

Among the different types of mulch, maximum dry matter production was observed at all stages in the treatment where rice straw was applied @ 5 t ha^{-1} (8.39, 86.12, 239.10 and 303.42 g plant^{-1} respectively), which was significantly superior to rice husk and coirpith compost mulch.

With regard to interactions between levels of hydrogel and types of mulch significant results were observed on dry matter production at 30, 60, 90 DAS and at harvest stage. At 30 and 60 DAS maximum dry matter production was recorded where hydrogel @ 3.75 kg ha^{-1} and rice straw @ 5 t ha^{-1} was applied (9.97 and 95.14 g plant^{-1} respectively) and was significantly superior to all other combinations. At 90 DAS, H_2M_1 (243.18 g plant^{-1}) recorded maximum dry matter production which was on par with the combinations of rice straw mulch with other levels of hydrogel and significantly superior to other combinations. At harvest H_2M_1 (320.58 g plant^{-1}) recorded maximum dry matter production which was on par with H_3M_1 and H_2M_2 and was significantly superior to all other combinations. When comparing the dry matter production in control with other treatments, it was found that the dry matter production in treatments varies from 15.78 % to 51.38 % over control. When comparing the percentage increase in dry matter production over control with the main effects of treatments Hydrogel @ 2.5 kg ha^{-1} (40.27 %) and rice straw mulch @ 5t ha^{-1} (43.28 %) recorded higher values. With regard to interactions, maximum percentage of dry matter production over control was recorded in H_2M_1 (51.28 %) followed by H_3M_1 (43.58 %). Dry matter production in control was significantly lower than all the treatments and their interactions at all stages of growth.

4.1.6 Root volume at harvest

The data on the effect of hydrogel and mulching on root volume of maize at harvest (Table 6) showed that there was significant difference among the levels of hydrogel, types of mulch and their interactions and control *versus* other treatments.

Among the levels of hydrogel, maximum root volume was recorded by hydrogel @2.5 kg ha^{-1} (25.50 cm^3) which was significantly superior to other levels of hydrogel. Among the types of mulch, maximum root volume was recorded by rice straw mulch@ 5 t ha^{-1} (24.17 cm^3) which was significantly superior to other types of mulch. With respect to interactions, H_2M_1 (27.50 cm^3) recorded maximum root volume and was on par with interaction H_3M_1 and was significantly superior to all other combinations. When compared the control with other treatments, control recorded lower root volume than the other treatments. The percentage increase in root volume over control was 47.14 % in treatment with hydrogel @ 2.5 kg ha^{-1} and 39.47 % in rice straw mulch applied plots. The treatment combination H_2M_1 (58.68 %) showed significantly higher percentage increase in root volume over control followed by H_3M_1 (46.16 %).

4.1.7 Relative Leaf Water Content (RLWC)

The data on the effect of hydrogel and mulching on RLWC at 30, 60 and 90 DAS are presented in Table 6. The RLWC showed significant difference among the levels of hydrogel at 30, 60 and 90 DAS. At 30 DAS maximum RLWC was observed where hydrogel was applied @ 1.25 kg ha^{-1} (89.75 %) which was on par with hydrogel level @ 3.75 kg ha^{-1}. At 60 and 90 DAS maximum RLWC was observed where hydrogel was applied @ 2.5 kg ha^{-1} (90.81 % and 88.97 % respectively) which was on par with hydrogel level @ 3.75 kg ha^{-1} at 60 DAS and was significantly superior to other levels of hydrogel at 90 DAS.

Table 6. Effect of hydrogel and mulching on root volume at harvest and RLWC

Treatment	Root volume	% increase	RLWC (%)		
Levels of hydrogel	at harvest (cm^3)	over control (Root volume at harvest)	30 DAS	60 DAS	90 DAS
H_1	20.44	17.95	89.75	89.12	84.70
H_2	25.50	47.14	88.47	90.81	88.97
H_3	21.33	23.08	89.32	90.40	85.85
SEm (±)	0.595		0.357	0.376	0.745
CD (0.05)	1.251		0.750	0.790	1.566
Types of mulch					
M_1	24.17	39.47	90.82	91.45	86.44
M_2	21.89	26.31	87.07	88.91	85.04
M_3	21.22	22.45	89.66	89.96	88.04
SEm (±)	0.595		0.357	0.376	0.745
CD (0.05)	1.251		0.750	0.790	1.566
Interactions					
H_1M_1	19.67	13.50	92.55	90.23	86.16
H_1M_2	20.67	19.27	86.14	86.42	81.12
H_1M_3	21.00	21.18	90.57	90.71	86.80
H_2M_1	27.50	58.68	89.30	91.44	86.55
H_2M_2	25.00	44.26	86.29	91.26	91.70
H_2M_3	24.00	38.49	89.82	89.74	88.65
H_3M_1	25.33	46.16	90.60	92.68	86.59
H_3M_2	20.00	15.41	88.77	89.07	82.30
H_3M_3	18.67	7.73	88.60	89.44	88.66
SEm (±)	1.031		0.618	0.651	1.291
CD (0.05)	2.167		1.299	1.368	2.712
Control *vs* other treatments					
Control	17.33		86.04	85.80	78.79
SEm (±)	0.769		0.461	0.485	0.962
CD (0.05)	1.615		0.968	1.019	2.022

Note: H_1 - hydrogel @ 1.25 kg ha^{-1}, H_2 - hydrogel @ 2.5 kg ha^{-1},

H_3 - hydrogel @ 3.75 kg ha^{-1}, M_1 - rice straw mulch @ 5 t ha^{-1},

M_2 - rice husk mulch @ 5 t ha^{-1}, M_3 - coirpith compost mulch @ 2.5 t ha^{-1}.

Among the types of mulch, the observation on RLWC was found significant at 30, 60 and 90 DAS. At 30 and 60 DAS the maximum RLWC was noticed with rice straw mulch @ 5 t ha^{-1} (90.82 % and 91.45 % respectively) which was significantly superior to other types of mulch. At 90 DAS the maximum RLWC was noticed in coirpith mulch @ 2.5 t ha^{-1} (88.04 %) which was significantly superior to other types of mulch.

With regard to interactions between levels of hydrogel and types of mulch showed significant effect on RLWC at 30, 60 and 90 DAS. At 30 DAS maximum RLWC was recorded by H_1M_1 (92.55 %) and at 60 DAS maximum RLWC was recorded by H_3M_1 (92.68 %) and it was on par with H_2M_1. At 90 DAS maximum RLWC was recorded by H_2M_2 (91.70 %) and was significantly superior to all other combinations. When compared with RLWC of control with other treatments, at all stages (30, 60 and 90 DAS) RLWC showed significant difference between control and other treatments. Control recorded a lower RLWC than the other treatments.

4.2 YIELD AND YIELD ATTRIBUTES

4.2.1 Number of cobs per plant

In each plant only one cob was observed in all the treatments.

4.2.2 Number of rows cob^{-1}

The results indicated that (Table 7) number of rows cob^{-1} was not affected by the levels of hydrogel, types of mulch and their interactions. It was observed that number of rows cob^{-1} was more or less same in control plot when compared with other treatments.

4.2.3 Length of cob

Length of cob (Table 7) was not significantly influenced by levels of hydrogel, types of mulch and their interactions. When compared with control, cob length showed significant difference and control recorded the lowest cob length.

Table 7. Effect of hydrogel and mulching on number of rows cob^{-1}, length of cob, girth of cob and number of grains cob^{-1}

Treatment / Levels of hydrogel	Number of rows cob^{-1}	Length of cob (cm)	Girth of cob (cm)	Number of grains cob^{-1}	% increase over control (Number of grains cob^{-1})
H_1	13.96	15.09	14.18	323.51	11.57
H_2	13.96	15.33	14.83	353.78	22.01
H_3	14.07	15.76	14.63	353.42	21.89
SEm (±)	0.290	0.320	0.353	5.367	
CD (0.05)	NS	NS	NS	11.276	
Types of mulch					
M_1	14.22	15.60	14.93	366.47	26.39
M_2	13.78	15.12	14.31	332.24	14.59
M_3	13.98	15.45	14.40	332.00	14.50
SEm (±)	0.290	0.320	0.353	5.367	
CD (0.05)	NS	NS	NS	11.276	
Interactions					
H_1M_1	14.13	15.25	14.18	337.53	16.41
H_1M_2	13.60	14.57	13.71	301.80	4.09
H_1M_3	14.13	15.44	14.66	331.20	14.23
H_2M_1	14.00	15.59	15.35	377.60	30.23
H_2M_2	13.60	15.01	14.69	346.00	19.33
H_2M_3	14.27	15.38	14.46	337.73	16.48
H_3M_1	14.53	15.95	15.26	384.27	32.53
H_3M_2	14.13	15.79	14.53	348.93	20.34
H_3M_3	13.53	15.53	14.09	327.07	12.80
SEm (±)	0.503	0.554	0.612	9.296	
CD (0.05)	NS	NS	NS	19.530	
Control *vs* other treatments					
Control	13.67	14.40	12.84	289.95	
SEm (±)	0.375	0.413	0.456	6.929	
CD (0.05)	NS	0.868	0.958	14.557	

Note: H_1 - hydrogel @ 1.25 kg ha^{-1}, H_2 - hydrogel @ 2.5 kg ha^{-1},

H_3 - hydrogel @ 3.75 kg ha^{-1}, M_1 - rice straw mulch @ 5 t ha^{-1},

M_2 - rice husk mulch @ 5 t ha^{-1}, M_3 - coirpith compost mulch @ 2.5 t ha^{-1}.

4.2.4 Girth of cob

Data on girth of cob (Table 7) showed that different treatments and their combinations did not have any significant influence on cob girth. The control recorded a significantly lower value when compared to other treatments.

4.2.5 Number of grains cob^{-1}

The data on number of grains cob^{-1} is presented in Table 7 indicated that number of grains cob^{-1} was significantly affected by the levels of hydrogel, types of mulch, their interactions and control *versus* other of treatments.

Among the levels of hydrogel, maximum number of grains cob^{-1} was recorded in treatment where hydrogel was applied @ 2.5 kg ha^{-1} (353.78) which was on par with hydrogel level @ 3.75 kg ha^{-1} (353.42) and both were significantly superior to hydrogel level @ 1.25 kg ha^{-1}. Among the types of mulch, maximum number of grains cob^{-1} was obtained in rice straw mulch @ 5 t ha^{-1} (366.47) and was significantly superior to rice husk and coirpith compost mulch. With respect to interactions, H_3M_1 (384.27) recorded maximum number of grains cob^{-1} which was on par with H_2M_1 (377.60) and significantly superior to other interactions. Control recorded significantly lower grains cob^{-1} compared to other treatments. The percentage increase in number of grains cob^{-1} over control was 22.01 % in treatment with hydrogel @ 2.5 kg ha^{-1} followed by hydrogel @ 3.75 kg ha^{-1} (21.89 %) and 26.39 % in rice straw mulch applied treatments. The treatment combination H_3M_1 (32.53 %) showed higher percentage increase in number of grains cob^{-1} over control followed by H_2M_1 (30.23 %).

4.2.6 Cob yield

The results on effect of hydrogel and mulching on cob yield of maize (Table 8) showed that cob yield was significantly influenced by levels of hydrogel, types of mulch, their interactions and control *versus* other treatments.

Among the different levels of hydrogel, maximum cob yield was observed with hydrogel @ 2.5 kg ha^{-1} (9.83 t ha^{-1}) which was significantly superior to other levels of hydrogel. Among the types of mulch, maximum cob yield was obtained with rice straw mulch @ 5 t ha^{-1} (10.50 t ha^{-1}) and was significantly superior to rice husk and coirpith compost mulch. Interactions between levels of hydrogel and types of mulch also significantly differed with regard to cob yield. The treatment combination H_2M_1 (11.13 t ha^{-1}) recorded maximum cob yield which was significantly superior to other treatment combinations. When the cob yield of control was compared with other treatments, it was observed that the cob yield was significantly lower in control.

4.2.7 Grain yield

The effect of hydrogel and mulching on grain yield of maize (Table 8) indicated that grain yield was significantly influenced by levels of hydrogel, types of mulch, their interactions and control *versus* other treatments.

Maximum grain yield was observed with hydrogel @ 2.5 kg ha^{-1} (8.03 t ha^{-1}) which was significantly superior to other levels of hydrogel. Among the types of mulch, maximum grain yield was obtained with rice straw mulch @ 5 t ha^{-1} (8.51 t ha^{-1}) and was significantly superior to rice husk and coirpith compost mulch.

Interactions between levels of hydrogel and types of mulch were significant with regard to grain yield. The treatment combination H_2M_1 (9.19 t ha^{-1}) recorded maximum grain yield which was significantly superior to other treatment combinations. When the grain yield of control was compared with other treatments, it was observed that the grain yield was significantly lower in control.

The percentage increase in grain yield over control was worked out and found that hydrogel @ 2.5 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1} produced 44.42 % and 53.06 % more yield respectively than control. All the interactions were superior to control and recorded a yield increase ranging from 16.37 % to 65.29 %.

Maximum increase in grain yield was observed in the treatment combination H_2M_1 (65.29%) followed by H_3M_1 (50.54 %).

4.2.8 Stover yield

The effect of hydrogel and mulching on stover yield of maize (Table 8) indicated that stover yield was significantly influenced by levels of hydrogel, types of mulch, their interactions and control *versus* other treatments.

Among the different levels of hydrogel, maximum stover yield was observed with hydrogel @ 2.5 kg ha^{-1} (10.65 t ha^{-1}) which was on par with hydrogel @ 1.25 kg ha^{-1} and significantly superior to other levels of hydrogel.

Among the types of mulch, maximum stover yield was obtained with rice straw mulch @ 5 t ha^{-1} (11.52 t ha^{-1}) and was significantly superior to rice husk and coirpith compost mulch. Interactions between levels of hydrogel and types of mulch were significant with regard to stover yield. The treatment combination H_2M_1 (12.02 t ha^{-1}) recorded maximum stover yield which was on par with H_3M_1 (11.46 t ha^{-1}) and significantly superior to other treatment combinations. When the stover yield of control was compared with other treatments, it was observed that the stover yield was significantly lower in control.

4.2.9 Test weight (100 grain weight)

Data pertained in Table 8 revealed that test weight was significantly influenced by types of mulch. Effect of hydrogel was not significant. Rice straw mulch @ 5 t ha^{-1} (32.05 grams) recorded maximum test weight and was significantly superior to rice husk and coirpith compost mulch. Among the interactions, combined effect of rice straw mulch with all the levels of hydrogel showed a higher test weight compared to other combinations. Control recorded significantly lower test weight than the other treatments.

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Table 8. Effect of hydrogel and mulching on cob yield, grain yield, stover yield, test weight and harvest index

Treatment Levels of hydrogel	Cob yield (t ha^{-1})	Grain yield (t ha^{-1})	% increase over control (Grain yield)	Stover yield (t ha^{-1})	Test weight (grams)	Harvest index
H_1	8.71	6.98	25.54	10.50	30.79	0.36
H_2	9.83	8.03	44.42	10.65	30.61	0.39
H_3	9.24	7.48	34.53	9.54	30.73	0.40
SEm (±)	0.186	0.125		0.217	0.659	0.009
CD (0.05)	0.392	0.263		0.456	NS	0.018
Types of mulch						
M_1	10.50	8.51	53.06	11.52	32.05	0.39
M_2	9.12	7.40	33.09	9.94	30.39	0.39
M_3	8.17	6.59	18.53	9.24	29.69	0.38
SEm (±)	0.186	0.125		0.217	0.659	0.009
CD (0.05)	0.392	0.263		0.456	1.385	NS
Interactions						
H_1M_1	10.01	7.97	43.35	11.07	31.59	0.38
H_1M_2	7.99	6.52	17.27	9.89	30.50	0.36
H_1M_3	8.14	6.47	16.37	10.54	30.28	0.35
H_2M_1	11.13	9.19	65.29	12.02	32.41	0.40
H_2M_2	9.91	8.10	45.68	10.87	30.37	0.39
H_2M_3	8.46	6.81	22.48	9.07	29.04	0.39
H_3M_1	10.36	8.37	50.54	11.46	32.17	0.38
H_3M_2	9.45	7.57	36.15	9.06	30.29	0.41
H_3M_3	7.91	6.48	16.55	8.11	29.74	0.40
SEm (±)	0.323	0.217		0.376	1.142	0.015
CD (0.05)	0.679	0.455		0.789	NS	NS
Control *vs* other treatments						
Control	7.62	5.56		7.96	28.81	0.36
SEm (±)	0.241	0.162		0.280	0.851	0.011
CD (0.05)	0.506	0.339		0.588	1.789	0.023

Note: H_1 - hydrogel @ 1.25 kg ha^{-1}, H_2 - hydrogel @ 2.5 kg ha^{-1},

H_3 - hydrogel @ 3.75 kg ha^{-1}, M_1 - rice straw mulch @ 5 t ha^{-1},

M_2 - rice husk mulch @ 5 t ha^{-1}, M_3 - coirpith compost mulch @ 2.5 t ha^{-1}.

4.2.10 Harvest index

The effect of hydrogel and mulching on harvest index of maize (Table 8) showed a significant difference among the levels of hydrogel and control *versus* other treatments while there was no significant difference among types of mulch and interactions between levels of hydrogel and types of mulch.

Among the levels of hydrogel, maximum harvest index was observed in hydrogel level @ 3.75 kg ha^{-1} (0.40) which was on par with hydrogel level @ 2.5 kg ha^{-1} and significantly superior to hydrogel level @ 1.25 kg ha^{-1}. When compared the control with other treatments, control recorded lower harvest index value than the other treatments. Effect of mulching and their interactions did not have any significant influence on harvest index.

4.3 PLANT ANALYSIS

4.3.1 Nutrient content of plant (N, P, K)

4.3.1.1 Nitrogen content of stover

Nitrogen content of stover was significantly influenced by the levels of hydrogel, types of mulch, their interactions and control *versus* other treatments (Table 9). Among the levels of hydrogel, maximum nitrogen content of stover was observed with hydrogel level @ 3.75 kg ha^{-1} (1.29 %) and was significantly superior to other two levels of hydrogel. Among the types of mulch, maximum nitrogen content was observed in rice straw mulch @ 5 t ha^{-1} (1.25 %) which was on par with rice husk mulch @ 5 t ha^{-1} and were significantly superior to coirpith compost mulch.

With respect to interactions, H_2M_1 (1.36 %) recorded maximum nitrogen content which was on par with H_3M_2 and H_3M_3 and significantly superior to other treatment combinations. Nitrogen content of stover in control plot was significantly lower than the other treatments.

Table 9. Effect of hydrogel and mulching on nutrient content of stover and grain

Treatment	Nutrient content of stover (%)			Nutrient content of grain (%)		
Levels of hydrogel	N	P	K	N	P	K
H_1	1.14	0.42	1.76	0.91	0.44	0.18
H_2	1.22	0.44	1.69	0.80	0.44	0.20
H_3	1.29	0.38	1.94	0.85	0.47	0.18
SEm (±)	0.026	0.014	0.031	0.023	0.016	0.005
CD (0.05)	0.054	0.029	0.065	0.048	NS	0.010
Types of mulch						
M_1	1.25	0.38	1.80	0.80	0.46	0.21
M_2	1.22	0.41	1.77	0.83	0.45	0.19
M_3	1.18	0.45	1.82	0.91	0.44	0.16
SEm (±)	0.026	0.014	0.031	0.023	0.016	0.005
CD (0.05)	0.054	0.029	NS	0.048	NS	0.010
Interactions						
H_1M_1	1.14	0.38	1.73	0.86	0.48	0.20
H_1M_2	1.21	0.43	1.87	0.73	0.46	0.21
H_1M_3	1.08	0.46	1.67	1.14	0.37	0.13
H_2M_1	1.36	0.41	1.65	0.82	0.44	0.20
H_2M_2	1.14	0.45	1.58	0.80	0.42	0.17
H_2M_3	1.16	0.46	1.83	0.77	0.47	0.24
H_3M_1	1.25	0.36	2.02	0.73	0.46	0.22
H_3M_2	1.31	0.35	1.87	0.97	0.47	0.20
H_3M_3	1.31	0.42	1.95	0.84	0.47	0.13
SEm (±)	0.044	0.024	0.054	0.039	0.028	0.008
CD (0.05)	0.093	NS	0.113	0.083	0.058	0.017
Control *vs* other treatments						
Control	1.01	0.38	1.60	0.65	0.42	0.20
SEm (±)	0.033	0.018	0.040	0.029	0.021	0.006
CD (0.05)	0.070	NS	0.084	0.062	NS	NS

Note: H_1 - hydrogel @ 1.25 kg ha^{-1}, H_2 - hydrogel @ 2.5 kg ha^{-1},

H_3 - hydrogel @ 3.75 kg ha^{-1}, M_1 - rice straw mulch @ 5 t ha^{-1},

M_2 - rice husk mulch @ 5 t ha^{-1}, M_3 - coirpith compost mulch @ 2.5 t ha^{-1}.

4.3.1.2 Nitrogen content of grain

Nitrogen content of grain was significantly influenced by the levels of hydrogel, types of mulch, their interactions and control *versus* other treatments (Table 9).

Among the levels of hydrogel, maximum nitrogen content of grain was recorded when hydrogel was applied @ 1.25 kg ha^{-1} (0.91 %) which was significantly superior to other levels of hydrogel. Among the types of mulch, maximum nitrogen content of grain was recorded in coirpith mulch @ 2.5 t ha^{-1} (0.91 %) and was significantly superior to other two types of mulch. With respect to interactions, H_1M_3 (1.14 %) recorded maximum nitrogen content of grain and was significantly superior to other treatment combinations. Nitrogen content of grain in control plot was significantly lower compared to the other treatments.

4.3.1.3 Phosphorus content of stover

Phosphorus content of stover was significantly influenced by levels of hydrogel and types of mulch (Table 9). Hydrogel @ 2.5 kg ha^{-1} (0.44 %) recorded maximum P content in stover which was on par with hydrogel @ 1.25 kg ha^{-1} and significantly superior to hydrogel @ 3.75 kg ha^{-1}. Among the types of mulch, maximum phosphorous content of stover was detected with coirpith compost mulch @ 2.5 t ha^{-1} (0.45 %) which was significantly superior to other two mulch types.

The interactions namely H_1M_2, H_1M_3, H_2M_2 and H_2M_3 recorded maximum P content in stover which were on par and significantly superior to all other combinations.

4.3.1.4 Phosphorus content of grain

The effect of hydrogel and mulch on phosphorous content of grain of maize (Table 9) indicated that phosphorous content was not significantly influenced by any one of the treatment. However, the interaction between the treatment combinations were significant. Among the interactions, H_1M_1 (0.477 %) recorded

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maximum phosphorous content of grain and was on par with H_3M_3, H_2M_3, H_3M_2, H_3M_1, H_1M_2, H_2M_1 and H_2M_2.

4.3.1.5 Potassium content of stover

A significant influence on K content of stover was observed by the application of hydrogel (Table 9) and the K content was maximum when hydrogel was applied @ 3.75 kg ha^{-1} (1.94 %) and was significantly superior to other two levels. Different types of mulches did not have any significant influence on K content of stover. However, their combinations showed significant difference and application of hydrogel @ 3.75 kg ha^{-1} along with rice straw mulch @ 5 t ha^{-1} (2.02 %) and coirpith compost mulch @ 2.5 t ha^{-1} (1.95 %) recorded maximum K content in stover which were on par and significantly superior to other combinations and control.

4.3.1.6 Potassium content of grain

Potassium content of grain was significantly influenced by levels of hydrogel, types of mulch and their interactions (Table 9). Hydrogel @ 2.5 kg ha^{-1} (0.20 %) gave maximum K content which was significantly superior to other two levels. Mulching with rice straw @ 5 t ha^{-1} (0.21 %) revealed maximum K content in the grain which was significantly superior to other types of mulches. With regards to interactions, H_2M_3 (0.24 %) recorded maximum potassium content of grain and was significantly superior to all other combinations.

4.3.2 Nutrient uptake (N, P, K)

4.3.2.1 Uptake of nitrogen by stover

The effect of hydrogel and mulching on nitrogen uptake by stover (Table 10) indicated that nitrogen uptake was significantly increased by the levels of hydrogel, types of mulch, their interactions and control *versus* other treatments.

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Among the levels of hydrogel, maximum nitrogen uptake by stover was observed in hydrogel level @ 2.5 kg ha^{-1} (156.64 kg ha^{-1}) and was significantly superior to other two levels. Rice straw mulch @ 5 t ha^{-1} (170.21 kg ha^{-1}) recorded maximum nitrogen uptake by stover and was significantly superior to other two types of mulches.

With regard to the interaction of treatments, rice straw mulch @ 5 t ha^{-1} along with hydrogel level @ 2.5 kg ha^{-1} (190.13 kg ha^{-1}) recorded the maximum value and was significantly superior to all other combinations. When compared with control, control recorded lower nitrogen uptake by stover than the other treatments.

4.3.2.2 Uptake of nitrogen by grain

Nitrogen uptake by grain was significantly influenced by levels of hydrogel, types of mulch, their interactions and control *versus* other treatments (Table 10).

Among the levels of hydrogel, maximum nitrogen uptake by grain was observed with hydrogel level @ 2.5 kg ha^{-1} (64.08 kg ha^{-1}) which was on par with hydrogel level @ 1.25 kg ha^{-1} and significantly superior to hydrogel level @ 3.75 kg ha^{-1}.

Among the types of mulch, maximum nitrogen uptake by grain was obtained by rice straw mulch @ 5 t ha^{-1} (68.26 kg ha^{-1}) and was superior to all other types of mulch.

With respect to interactions, H_2M_1 (75.51 kg ha^{-1}) recorded maximum nitrogen uptake by grain and was superior to all other combinations. When control was compared with other treatments, it was found that control recorded a lower uptake by grain than the other treatments.

4.3.2.3 Total nitrogen uptake

Total nitrogen uptake (Table 10) was significantly influenced by levels of hydrogel, types of mulch, their interactions and control *versus* other treatments.

Hydrogel @ 2.5 kg ha^{-1} (220.83 kg ha^{-1}) recorded maximum nitrogen uptake which was significantly superior to other two levels. Among the types of mulch, total nitrogen uptake was maximum in rice straw mulch applied @ 5 t ha^{-1} (238.47 kg ha^{-1}) and was significantly superior to other two types of mulch. With respect to interactions, H_2M_1 (265.64 kg ha^{-1}) recorded maximum total nitrogen uptake and was significantly superior to all other combinations. Control recorded lower nitrogen uptake and was significantly lower than the other treatments.

4.3.2.4 Uptake of phosphorus by stover

The effect of hydrogel and mulching on phosphorus uptake by stover was given in Table 10. The results indicated that phosphorus uptake of stover was significantly influenced by the levels of hydrogel, types of mulch, their interactions and control *versus* other treatments.

Among the levels of hydrogel, maximum phosphorus uptake was recorded by hydrogel @ 2.5 kg ha^{-1}(53.70 kg ha^{-1}) which was on par with hydrogel level @ 1.25 kg ha^{-1} and was significantly superior to hydrogel @ 3.75 kg ha^{-1}. Maximum phosphorus uptake by stover was obtained in rice straw mulch @ 5 t ha^{-1} (51.51 kg ha^{-1}) which was on par with coirpith mulch @ 2.5 t ha^{-1} and was significantly superior to rice husk mulch.

With respect to interactions, H_1M_3 (58.36 kg ha^{-1}) recorded maximum phosphorus uptake by stover and was on par with H_2M_1 and H_2M_2. When control was compared with other treatments, control was found to have lower phosphorus uptake by stover than the other treatments.

4.3.2.5 Uptake of phosphorus by grain

The effect of hydrogel and mulching on phosphorus uptake of grain (Table 10) indicated that phosphorus uptake of grain was significantly influenced by the levels of hydrogel, types of mulch, their interactions and control *versus* other treatments.

Maximum phosphorus uptake by grain was recorded by hydrogel @ 2.5 kg ha^{-1} (35.45 kg ha^{-1}) which was on par with hydrogel @ 3.75 kg ha^{-1} and was significantly superior to hydrogel @ 1.25 kg ha^{-1}. Among the types of mulch, maximum phosphorus uptake by grain was obtained in rice straw mulch @ 5 t ha^{-1} (39.15 kg ha^{-1}) and was significantly superior to other types of mulches.

With respect to interactions, H_2M_1 (40.68 kg ha^{-1}) recorded maximum phosphorus uptake by grain which was on par with H_3M_1 and superior to other combinations. When compared with control, it was found that control was significantly inferior to all the treatments and its combinations.

4.3.2.6 Total phosphorus uptake

As observed in the phosphorus uptake of stover and grain, total phosphorus uptake was also significantly influenced by different treatments and their combinations (Table 10). Hydrogel @ 2.5 kg ha^{-1} (89.15 kg ha^{-1}) and rice straw mulch @ 5 t ha^{-1} (90.66 kg ha^{-1}) and its combination (97.84 kg ha^{-1}) recorded maximum P uptake and were significantly superior to other treatments.

4.3.2.7 Uptake of potassium by stover

The data given in table 10 showed that potassium uptake was significantly influenced by the levels of hydrogel, types of mulch, their interactions and control *versus* other treatments.

Hydrogel @ 3.75 kg ha^{-1} (220.35 kg ha^{-1}) recorded maximum potassium uptake by stover and was significantly superior to other two levels of hydrogel.

Maximum potassium uptake by stover was obtained in rice straw mulch @ 5 t ha^{-1} (241.76 kg ha^{-1}) and was significantly superior to other types of mulch. Among the interactions, H_3M_1 (269.33 kg ha^{-1}) recorded maximum potassium uptake by stover. When control was compared with other treatments, it was observed that potassium uptake by stover was significantly lower than the other treatments.

4.3.2.8 Uptake of potassium by grain

Significant effect on potassium uptake of grain (Table 10) was observed by the application of the levels of hydrogel, types of mulch, their interactions and control *versus* other treatments.

Hydrogel @ 2.5 kg ha^{-1} (16.27 kg ha^{-1}) recorded maximum potassium uptake by grain and was significantly superior to other levels of hydrogel. Maximum potassium uptake by grain was obtained in rice straw mulch @ 5 t ha^{-1} (17.59 kg ha^{-1}) and was significantly superior to other types of mulch. Among interactions, H_2M_1 (18.76 kg ha^{-1}) recorded maximum potassium uptake by grain which was on par with interaction H_3M_1 and significantly superior to other combinations. Control recorded a lower K uptake by grain and was significantly lower than other treatments.

4.3.2.9 Total potassium uptake

Total potassium uptake (Table 10) was significantly influenced by the levels of hydrogel, types of mulch, their interactions and control *versus* other treatments. Hydrogel @ 3.75 kg ha^{-1} (234.29 kg ha^{-1}) recorded maximum potassium uptake which was significantly superior to other two levels. Among the types of mulch, maximum total potassium uptake was obtained in rice straw mulch @ 5 t ha^{-1} (259.35 kg ha^{-1}) and was significantly superior to other two types of mulch. With respect to interactions, H_3M_1 (287.37 kg ha^{-1}) recorded maximum total potassium uptake and was significantly superior to all other combinations. Control recorded lower potassium uptake and was significantly lower than the other treatments.

Table 10. Effect of hydrogel and mulching on stover, grain and total nutrient uptake

Treatment	Stover uptake (Kg ha^{-1})			Grain uptake (Kg ha^{-1})			Total uptake (Kg ha^{-1})		
Levels of hydrogel	N	P	K	N	P	K	N	P	K
H_1	140.39	53.04	210.33	63.18	30.66	12.52	203.57	83.70	222.84
H_2	156.64	53.70	212.12	64.08	35.45	16.27	220.83	89.15	228.37
H_3	145.38	42.32	220.35	62.95	34.99	13.95	208.33	77.32	234.29
SEm (±)	2.260	1.124	1.952	0.434	0.539	0.414	2.944	1.363	2.605
CD (0.05)	4.749	2.361	4.100	0.912	1.132	0.870	6.185	2.865	5.473
Types of mulch									
M_1	170.21	51.51	241.76	68.26	39.15	17.59	238.47	90.66	259.35
M_2	143.90	48.25	205.65	61.87	33.21	14.27	205.88	81.46	219.87
M_3	128.31	49.30	195.39	60.07	28.75	10.87	188.37	78.04	206.28
SEm (±)	2.260	1.124	1.952	0.434	0.539	0.414	2.944	1.363	2.605
CD (0.05)	4.749	2.361	4.100	0.912	1.132	0.870	6.185	2.865	5.473
Interactions									
H_1M_1	149.85	49.09	223.64	68.35	37.72	15.93	218.20	86.81	239.60
H_1M_2	135.61	51.66	204.25	47.53	30.31	13.48	183.15	81.97	217.67
H_1M_3	135.70	58.36	203.08	73.66	23.96	8.16	209.36	82.32	211.24
H_2M_1	190.13	57.16	232.32	75.51	40.68	18.76	265.64	97.84	251.09
H_2M_2	155.79	54.29	207.83	64.63	33.88	13.87	220.75	88.18	221.60
H_2M_3	124.01	49.65	196.22	52.09	31.79	16.17	176.09	81.44	212.41
H_3M_1	170.63	48.28	269.33	60.94	39.06	18.08	231.57	87.34	287.37
H_3M_2	140.30	38.81	204.86	73.45	35.43	15.46	213.74	74.24	220.32
H_3M_3	125.21	39.88	186.87	54.45	30.50	8.29	179.66	70.37	195.18
SEm (±)	3.915	1.946	3.380	0.752	0.933	0.717	5.098	2.362	4.512
CD (0.05)	8.226	4.089	7.102	1.580	1.960	1.506	10.712	4.962	9.480
Control *vs* other treatments									
Control	90.81	34.39	148.71	36.29	23.24	11.01	127.10	57.63	159.73
SEm (±)	2.918	1.451	2.520	0.560	0.695	0.534	3.800	1.760	3.363
CD (0.05)	6.131	3.048	5.294	1.177	1.461	1.123	7.984	3.698	7.066

Note: H_1 - hydrogel @ 1.25 kg ha^{-1}, H_2 - hydrogel @ 2.5 kg ha^{-1},

H_3 - hydrogel @ 3.75 kg ha^{-1}, M_1 - rice straw mulch @ 5 t ha^{-1},

M_2 - rice husk mulch @ 5 t ha^{-1}, M_3 - coirpith compost mulch @ 2.5 t ha^{-1}.

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4.4 SOIL ANALYSIS

4.4.1 Soil moisture

4.4.1.1 Soil moisture at 15 cm depth

The data on the effect of hydrogel and mulching on soil moisture status (15 cm depth) at 30, 60, 90 DAS and at harvest stage are presented in Table 11. Soil moisture content at 15 cm depth showed a significant difference among the levels of hydrogel at 30, 60 and 90 DAS and was non-significant at harvest stage. Maximum soil moisture content was observed (15 cm depth) at 30, 60 and 90 DAS, when hydrogel was applied @ 3.75 kg ha^{-1} (4.01 %, 3.45 % and 4.20 % respectively) and was significantly superior to other two levels of hydrogel.

Among the types of mulch, the observation on soil moisture content at 15 cm depth showed significant difference at 30, 90 DAS and at harvest stage and was non-significant at 60 DAS. At 30 and 90 DAS and at harvest stage the maximum soil moisture content at 15 cm depth was noticed with rice straw mulch @ 5 t ha^{-1} (4.14 %, 4.19 % and 2.24 % respectively) which was significantly superior to other types of mulch and at harvest stage it was on par with the rice husk mulch @ 5 t ha^{-1}.

Combinations of levels of hydrogel and types of mulches showed significant results on soil moisture content at 15 cm depth. At 30 DAS, H_3M_1 (4.78 %) recorded maximum soil moisture which was significantly superior to all other combinations. At 60 DAS, H_2M_3 (3.75 %) recorded maximum soil moisture content at 15 cm depth which was on par with H_3M_1, H_3M_2 and H_2M_1. At 90 DAS H_3M_1 (4.60 %) recorded the maximum moisture content. At harvest stage H_2M_1 (2.71 %) recorded the maximum moisture content at 15 cm depth which was on par with H_3M_2 and significantly superior to all other combinations. Comparison of soil moisture content of control with other treatment revealed that soil moisture at 15 cm depth in control was significantly lower than other treatments at 30, 60, 90 DAS and at harvest stage.

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Table 11. Effect of hydrogel and mulching on soil moisture content at 15 cm and 30 cm depth

Treatment	Soil moisture at 15 cm depth (%)				Soil moisture at 30 cm depth (%)				
Levels of hydrogel	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	% increase over control at harvest
H_1	3.32	2.42	3.32	1.94	3.57	2.86	3.46	2.40	29.73
H_2	3.75	3.18	3.90	2.07	3.92	3.50	4.11	2.98	61.08
H_3	4.01	3.45	4.20	2.04	4.14	3.53	4.55	3.42	84.86
SEm (±)	0.090	0.225	0.061	0.156	0.061	0.198	0.076	0.103	
CD (0.05)	0.190	0.472	0.127	NS	0.128	0.415	0.159	0.217	
Types of mulch									
M_1	4.14	3.21	4.19	2.24	4.35	3.58	4.35	3.37	82.16
M_2	3.36	2.88	3.59	2.01	3.57	2.92	3.80	2.53	36.76
M_3	3.57	2.96	3.64	1.80	3.71	3.39	3.97	2.90	56.76
SEm (±)	0.090	0.225	0.061	0.156	0.061	0.198	0.076	0.103	
CD (0.05)	0.190	NS	0.127	0.328	0.128	0.415	0.159	0.217	
Interactions									
H_1M_1	3.35	2.81	3.54	2.05	3.77	3.43	3.56	2.37	28.11
H_1M_2	3.29	2.23	3.14	1.84	3.38	2.46	3.31	2.29	23.78
H_1M_3	3.31	2.23	3.28	1.93	3.55	2.68	3.52	2.53	36.76
H_2M_1	4.30	3.09	4.10	2.71	4.40	2.77	4.42	3.56	92.43
H_2M_2	3.34	2.69	3.76	1.95	3.65	3.68	3.91	2.56	38.38
H_2M_3	3.60	3.75	3.83	1.55	3.71	4.06	3.99	2.83	52.97
H_3M_1	4.78	3.73	4.60	1.97	4.88	4.53	5.07	4.19	126.49
H_3M_2	3.44	3.71	3.86	2.24	3.68	2.62	4.18	2.75	48.65
H_3M_3	3.81	2.90	3.80	1.91	3.87	3.43	4.39	3.33	80.00
SEm (±)	0.156	0.389	0.105	0.271	0.106	0.342	0.076	0.179	
CD (0.05)	0.329	0.817	0.221	0.569	0.222	0.719	0.159	0.376	
Control *vs* other treatments									
Control	1.74	1.95	2.96	1.33	2.11	3.25	2.92	1.85	
SEm (±)	0.117	0.290	0.078	0.202	0.079	0.255	0.098	0.133	
CD (0.05)	0.245	0.609	0.164	0.424	0.165	NS	0.206	0.280	

Note: H_1 - hydrogel @ 1.25 kg ha^{-1}, H_2 - hydrogel @ 2.5 kg ha^{-1},

H_3 - hydrogel @ 3.75 kg ha^{-1}, M_1 - rice straw mulch @ 5 t ha^{-1},

M_2 - rice husk mulch @ 5 t ha^{-1}, M_3 - coirpith compost mulch @ 2.5 t ha^{-1}.

4.4.1.2 Soil moisture at 30 cm depth

The data presented in Table 11 showed that hydrogel and mulch had significant effect on soil moisture (30 cm depth) at 30, 60 and 90 DAS and at harvest stage.

The soil moisture content at 30 cm depth showed a significant difference among the levels of hydrogel at 30, 60 and 90 DAS and at harvest stage. Maximum soil moisture content at 30 cm depth was observed in hydrogel level @ 3.75 kg ha^{-1} (4.14 %, 3.53 %, 4.55 % and 3.42 % respectively) and was on par with hydrogel level @ 2.5 kg ha^{-1} at 60 DAS.

Among the types of mulch, the observation on soil moisture content at 30 cm depth was found significant at 30, 60 and 90 DAS and at harvest stage. At all stages (30, 60, 90 DAS and harvest stage) the maximum soil moisture content at 30 cm depth was recorded by rice straw mulch @ 5 t ha^{-1} (4.35 %, 3.58 %, 4.35 % and 3.37 % respectively) which was significantly superior to other types of mulch except at 60 DAS. At 60 DAS it was on par with coirpith compost mulch.

Combined application of hydrogel and mulch was found significant at 30, 60 and 90 DAS and at harvest stage. At all stages (30, 60, 90 DAS and harvest stage) the maximum soil moisture content at 30 cm depth was recorded by H_3M_1 (4.88 %, 4.53 %, 5.07 % and 4.19 %) which was on par with H_2M_3 at 60 DAS and was significantly superior to other combinations. Control had significantly lower moisture content at 30, 60, 90 DAS and at harvest stage when compared with other treatments.

The increase in soil moisture content over control was worked out at harvest stage. The results indicated that there was pronounced increase in soil moisture at 30 cm depth due to application of hydrogel, mulch and their combinations. Application of hydrogel @ 3.75 kg ha^{-1} recorded an increase of 84.86 % and rice straw mulch recorded 82.16% over absolute control. A cumulative increase of 126.49 % was observed when hydrogel @ 3.75 kg ha^{-1} was combined with rice straw mulch @ 5 t ha^{-1} which was followed by H_2M_1 (92.43%) and H_3M_3 (80.00 %).

4.4.2 Bulk density of soil at harvest

The data on bulk density of soil after the harvest of maize crop as influenced by the levels of hydrogel and types of mulch (Table 12) indicated that there was no significant difference between the levels of hydrogel, types of mulches, their interactions and control.

4.4.3 Porosity of soil at harvest

The data on porosity of soil after the harvest of the crop is presented in Table 12. The results showed that porosity of soil was significantly influenced by levels of hydrogel and types of mulch and no significant difference was observed between interactions of levels of hydrogel and types of mulch and control.

Among the levels of hydrogel, maximum porosity was observed in hydrogel applied @ 3.75 kg ha^{-1} (43.64 %) which was significantly superior to other levels of hydrogel. Among the types of mulch, maximum porosity was observed with coirpith compost mulch @ 2.5 t ha^{-1} (43.56 %) which was significantly superior to other two types of mulch.

4.4.4 Nutrient status of soil at harvest

4.4.4.1 Available nitrogen

Data on nitrogen content of soil presented in Table 12 showed that hydrogel @ 1.25 kg ha^{-1} (238.34 kg ha^{-1}) recorded higher nitrogen content than other two levels of hydrogel. Rice husk mulch @ 5 t ha^{-1} (236.94 kg ha^{-1}) recorded higher nitrogen content followed by coirpith compost @ 2.5 t ha^{-1} which was on par and superior to rice straw mulch.

Table 12. Effect of hydrogel and mulching in bulk density, porosity and nutrient content of soil

Treatment	Bulk density of soil (g cc^{-1})	Porosity of soil (%)	Nutrient content of soil (kg ha^{-1})		
Levels of hydrogel			N	P_2O_5	K_2O
H_1	1.43	42.93	238.34	64.63	276.12
H_2	1.42	43.20	232.76	62.47	230.27
H_3	1.42	43.64	204.89	68.02	202.44
SEm (±)	0.013	0.159	1.958	1.197	9.167
CD (0.05)	NS	0.334	4.114	2.515	19.260
Types of mulch					
M_1	1.42	43.07	204.89	55.91	200.55
M_2	1.42	43.16	236.94	76.97	268.29
M_3	1.41	43.56	234.15	62.24	239.98
SEm (±)	0.013	0.159	1.958	1.197	9.167
CD (0.05)	NS	0.334	4.114	2.515	19.260
Interactions					
H_1M_1	1.43	42.80	234.15	58.56	223.10
H_1M_2	1.43	42.80	246.70	72.50	319.42
H_1M_3	1.42	43.20	234.15	62.84	285.82
H_2M_1	1.43	42.80	217.43	48.65	192.64
H_2M_2	1.41	43.47	238.34	72.58	246.40
H_2M_3	1.42	43.33	242.52	66.17	251.78
H_3M_1	1.41	43.60	163.07	60.53	185.92
H_3M_2	1.42	43.20	225.79	85.84	239.05
H_3M_3	1.40	44.13	225.79	57.71	182.34
SEm (±)	0.022	0.275	3.391	2.073	15.878
CD (0.05)	NS	NS	7.125	4.356	33.359
Control *vs* other treatments					
Control	1.41	43.47	250.88	85.49	299.71
SEm (±)	0.016	0.205	2.528	1.545	11.835
CD (0.05)	NS	NS	5.311	3.247	24.864

Note: H_1 - hydrogel @ 1.25 kg ha^{-1}, H_2 - hydrogel @ 2.5 kg ha^{-1},

H_3 - hydrogel @ 3.75 kg ha^{-1}, M_1 - rice straw mulch @ 5 t ha^{-1},

M_2 - rice husk mulch @ 5 t ha^{-1}, M_3 - coirpith compost mulch @ 2.5 t ha^{-1}.

Among the interactions, H_1M_2 (246.70 kg ha^{-1}) recorded maximum soil nitrogen content and was on par with H_2M_3. When control was compared with other treatments, control recorded higher soil nitrogen content of soil than the other treatments.

4.4.4.2 Available phosphorus

Phosphorus content of soil was significantly influenced by the levels of hydrogel, types of mulch, their interactions and control *versus* other treatments (Table 12).

Among the levels of hydrogel, maximum soil phosphorus content was observed with hydrogel @ 3.75 kg ha^{-1} (68.02 kg ha^{-1}) which was significantly superior to other two levels of hydrogel. Among the types of mulch, maximum soil phosphorus content was observed with rice husk mulch @ 5 t ha^{-1} (76.97 kg ha^{-1}) which was significantly superior to other two types of mulch. With respect to interactions, H_3M_2 (85.84 kg ha^{-1}) recorded maximum soil phosphorus content and was significantly superior than other combinations. When compared the control with other treatments, control had higher soil phosphorus content of soil than the other treatments.

4.4.4.3 Available potassium

The effect of hydrogel and mulching on potassium content of soil (Table 12) indicated that potassium content was significantly influenced by the levels of hydrogel, types of mulch, their interactions and control *versus* other treatments.

Among the levels of hydrogel, maximum soil potassium content was observed in hydrogel @ 1.25 kg ha^{-1} (276.12 kg ha^{-1}) which was significantly superior to other two levels. Among the types of mulch maximum potassium content of soil was recorded by rice husk mulch @ 5 t ha^{-1} (268.29 kg ha^{-1}) and was significantly superior to other two types of mulch. With respect to interactions, H_1M_2 (319.42 kg ha^{-1}) recorded maximum soil potassium content which was superior to other combinations. When control was compared with other treatments, control recorded higher potassium content of soil than the other treatments.

4.5 ECONOMICS

4.5.1 Gross income

The gross income was significantly influenced by levels of hydrogel, types of mulches, their interactions and control *versus* other treatments (Table 13).

Hydrogel @ 2.5 kg ha^{-1} (₹ 2,83,654) recorded maximum gross income and was significantly superior to other two levels. Maximum gross income was obtained in rice straw mulch @ 5 t ha^{-1} (₹ 3,01,426). With respect to interactions, H_2M_1 (₹ 3,23,907) recorded maximum net income which was significantly superior to other combinations. When control was compared with other treatments, it was found that control recorded lower gross income than the other treatments.

5.2.2 Net income

The data on net income (Table 13) showed that net income was significantly influenced by levels of hydrogel, types of mulch, their interactions and control *versus* other treatments.

Hydrogel @ 2.5 kg ha^{-1} (₹ 1,25,479) was recorded maximum net income and was significantly superior to other levels. Maximum net income was obtained in rice straw mulch @ 5 t ha^{-1} (₹ 1,21,584) and was significantly superior to other two types of mulch. With respect to interactions, H_2M_1 (₹1,44,065) recorded maximum net income which was significantly superior to other combinations. When control was compared with other treatments, it was found that control recorded lower net income than the other treatments.

Table 13. Effect of hydrogel and mulching on Gross income, net income and BCR

Treatment	Economics		
Levels of hydrogel	Gross income (₹)	Net income (₹)	BCR
H_1	251537	80862	1.48
H_2	283654	125479	1.80
H_3	262451	104275	1.66
SEm (±)	1082.31	1199.97	0.008
CD (0.05)	2273.93	2521.14	0.018
Types of mulch			
M_1	301426	121584	1.68
M_2	261623	109282	1.73
M_3	234592	79751	1.53
SEm (±)	1082.31	1199.97	0.008
CD (0.05)	2273.93	2521.14	0.018
Interactions			
H_1M_1	283296	103454	1.58
H_1M_2	235055	82714	1.54
H_1M_3	236259	56417	1.31
H_2M_1	323907	144065	1.80
H_2M_2	286370	134028	1.92
H_2M_3	240685	98343	1.69
H_3M_1	297074	117232	1.65
H_3M_2	263444	111103	1.73
H_3M_3	226833	84491	1.59
SEm (±)	1874.61	2078.41	0.015
CD (0.05)	3938.57	4366.73	0.030
Control *vs* other treatments			
Control	198630	63288	1.47
SEm (±)	1397.25	1549.15	0.011
CD (0.05)	2935.63	3254.77	0.023

Note: H_1 - hydrogel @ 1.25 kg ha^{-1}, H_2 - hydrogel @ 2.5 kg ha^{-1},

H_3 - hydrogel @ 3.75 kg ha^{-1}, M_1 - rice straw mulch @ 5 t ha^{-1},

M_2 - rice husk mulch @ 5 t ha^{-1}, M_3 - coirpith compost mulch @ 2.5 t ha^{-1}.

Prices of inputs: Rice straw - ₹ 8 kg^{-1}, rice husk - ₹ 2.5 kg^{-1}, coirpith compost - ₹ 10 kg^{-1},

hydrogel - ₹ 1800 kg^{-1}

Prices of outputs: Maize grains: ₹ 30 kg^{-1}, maize stover: ₹ 4 kg^{-1}

4.5.3 BCR

The BCR was significantly influenced by levels of hydrogel, types of mulch and control *versus* other treatments (Table 13).

Hydrogel @ 2.5 kg ha^{-1} (1.80) recorded maximum BCR and was significantly superior to other two levels of hydrogel. Maximum BCR was obtained in rice husk mulch @ 5 t ha^{-1} (1.73) which was significantly superior to other two types of mulch. With respect to interactions, H_2M_2 (1.92) recorded maximum BCR which was significantly superior than other combinations. When control was compared with other treatments, it was found that control recorded lower BCR than the other treatments.

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DISCUSSION

5. DISCUSSION

The experiment entitled "Effect of hydrogel and mulching on maize (*Zea mays* L.) in sandy soil" was carried out during 2017-18 at College of Agriculture, Padannakkad. The study aimed to critically evaluate the results of different treatments on various growth and yield parameters of maize and presented in an intangible way. Whenever necessary, investigational reports of others have been quoted for supporting the outcome of present experiment.

5.1 EFFECT OF HYDROGEL AND MULCHING ON GROWTH AND GROWTH PARAMETERS OF MAIZE

Growth is an irreversible permanent increase in size of an organ or its parts or even of an individual cell. In all the treatments plant height reached maximum up to 60 DAS and after that there was no increase in plant height due to tassel development. At initial stages (30 DAS) of the maize crop, among three levels of hydrogel, the application of hydrogel @ 2.5 kg ha^{-1} showed significant effect on the plant height but at later stages (60 DAS) the effect was not significant. Rice straw mulch @ 5 t ha^{-1} showed significant effect on the height of the maize at 30 and 60 DAS. Among the interactions hydrogel @ 2.5 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1} recorded the maximum plant height at 30 DAS. All the treatments recorded more height than control at 30 and 60 DAS (Table 4). The increased plant height in maize might be due to high water holding capacity of hydrogel and reduced evaporation by rice straw mulch which in turn increase the availability of nutrients to the plants and ultimately leading to increased plant height. Increased plant height due to hydrogel application was also observed by the Mao *et al*. (2011), Islam *et al*. (2011) and Kumari *et al*. (2017) and due to straw mulch application was reported by Uwah and Iwo (2011).

The number of leaves $plant^{-1}$ increased from 30 DAS to 60 DAS and thereafter decreased gradually till harvest stage. Application of rice straw mulch @ 5 t ha^{-1} showed significant difference at 60 and 90 DAS and all treatments recorded more number of leaves than control at 30 and 90 DAS (Table 4). Mulching with rice straw retained the soil moisture for a longer period in the root zone of the crop may extend the senescence of lower leaves. This is further supported by high RLWC of the leaves in this treatment as RLWC is an indication of leaf turgidity or water deficits in plants (Table 6). This was in line with the findings of Wang *et al.* (2011) and Uwah and Iwo (2011).

Increased leaf area is an index of photosynthetic capacity of the plant. LAI is an important index to study the structure and function of farmland ecosystem and crop canopy structure and the size of LAI affect stover and grain yield directly (Feng *et al.*, 2013; Verger *et al.*, 2014). Maximum leaf area and LAI was observed with main and interaction effects of treatments having hydrogel @ 3.75 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1} at all the stages which was on par with H_2M_1 at 60 and 90 DAS and with H_1M_1 at 90 DAS (Fig. 3). Control plot recorded a lower leaf area and LAI than the remaining treatments (Table 4 and Table 5). It was also observed that there was a decrease in the leaf area and LAI from 60 DAS to harvest stage but the rate of decrease was higher in control plot. This might be due to more number of leaves $plant^{-1}$ and high RLWC especially in the case of rice straw mulch@ 5 t ha^{-1} and hydrogel @ 3.75 kg ha^{-1} and 2.5 kg ha^{-1}. Decreased moisture content of plant resulted in decreased cell volume due to lower turgor pressure and consequent increase in solute concentration in cells. Hydrogel and rice straw mulch increase the turgor pressure inside the cells by maintaining adequate amount of moisture as per plant need and thus increased the leaf area and LAI (Yazdani *et al.*, 2007).

Dry matter production is an indication of efficient use of resources. Dry matter accumulation of maize mainly from leaves, since photosynthesis mainly occurs in the maize leaves, and LAI determines the yield of maize. Maize growth is depending on the ability of the plant canopy to absorb incoming radiation and translate it into dry matter (Gifford *et al.*, 1984). Total dry matter production $plant^{-1}$ (Table 5) increased from 30 DAS to harvest stage in all the treatments. This increase may be attributed to an increased leaf area and LAI. Effect of hydrogel on dry matter production was significant at 30, 60 DAS and at harvest stage. Hydrogel applied @ 3.75 kg ha^{-1} showed the maximum dry matter production at 30 and 60

DAS and at harvest stage hydrogel applied @ 2.5 kg ha^{-1} recorded the maximum dry matter production (Fig. 4). The increased dry matter production at harvest stage with the application of hydrogel @ 2.5 kg ha^{-1} was due to retention of more number of healthy and turgid leaves in the plant compared to other levels of hydrogel. This was further supported by the root volume at harvest stage (Table 6 and Fig. 5). The root volume at harvest stage indicated that application of hydrogel @ 2.5 kg ha^{-1} may be the optimum dose as further increase in quantity of hydrogel reduced the root volume significantly which directly influence the uptake of water and nutrients and finally the growth and dry matter production. Application of rice straw mulch @ 5 t ha^{-1} recorded the maximum dry matter production at 30, 60and 90 DAS and at harvest stage.

In general, hydrogel @ 3.75 kg ha^{-1} along with rice straw mulch @ 5 t ha^{-1} recorded the maximum dry matter production at early growth stages but later stages hydrogel @ 2.5 kg ha^{-1} with rice straw mulch @ 5 t ha^{-1} recorded the maximum dry matter production and was on par with rice straw mulch with other two levels of hydrogel at 90 DAS and again with hydrogel level @ 3.75 kg ha^{-1} at harvest stage. With respect to percentage increase in dry matter production, hydrogel @ 2.5 kg ha^{-1}, rice straw mulch @ 5 t ha^{-1} and their combination recorded 40.27, 43.2 and, 51.38 % respectively over control (Table 5). Moisture stress during the growth stages of the crop decreases the capacity of protoplasm to carry photosynthesis and translocation of photo assimilates. This in turn affects the translocation of photosynthate and growth regulators and creates disturbances in nitrogen metabolism. This ultimately resulted in reduced turgor of leaves and decreased growth (Kramer, 1969). El-Salmawi (2007) stated that increase in dry matter production was due to increase in carbohydrates, proteins, total amino acids and other biochemical and physiological parameters especially in the presence of hydrogel.

Plate 1. General view of experimental site

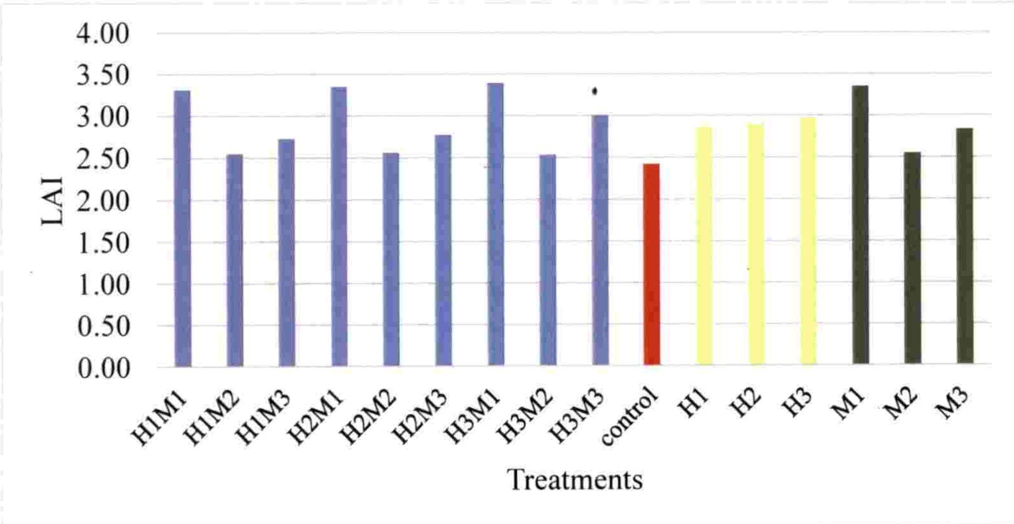

Fig. 3. Effect of hydrogel and mulch on LAI at 90 DAS

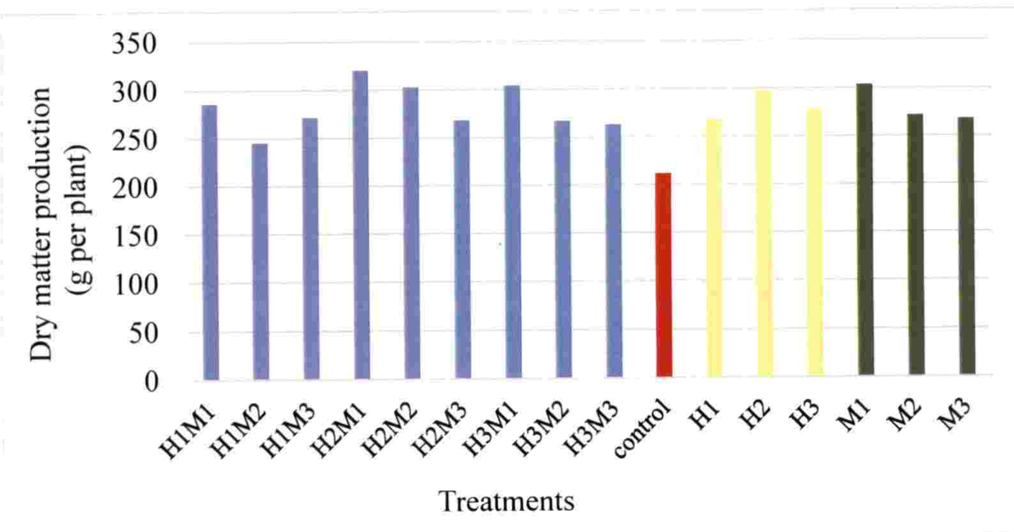

Fig. 4. Effect of hydrogel and mulch on dry matter production (g plant^{-1}) at harvest stage

Similarly, a significant increase in dry matter production due to hydrogel application was reported by Silberbush *et al.* (1993) in maize, Akhter *et al.* (2004) in barley and wheat and Yazdani *et al.* (2007) in soybean and due to straw mulch application by Khan and Parvej (2010), Ma *et al.* (2017) and Yin *et al.* (2017) in maize.

The high soil moisture content and increased root spread improves the accessibility of plant roots to nutrients (Sarkar, 2005). The results on root volume (Table 6 and Fig. 4) of maize plant was found maximum with the main and interaction effects of hydrogel application @ 2.5 kg ha^{-1} and rice straw mulch application @ 5 t ha^{-1} which was on par with interaction of hydrogel @ 3.75 kg ha^{-1} with rice straw mulch @ 5 t ha^{-1}. When comparing all the treatment combinations with control, control showed a lower root volume than the other treatments. Hydrogel application @ 2.5 kg ha^{-1} recorded 47.14 %, rice straw mulch application @ 5 t ha^{-1} recorded 39.47 % and their combination recorded 58.68 % more root volume over control (Table 6 and Fig. 5). The increased root volume due to hydrogel and straw mulch application was due to increased availability of water and nutrients for a longer period of time and maintenance of soil temperature and aeration for better root growth near the root zone of the crop.

Application of hydrogel increased the porosity of the soil (Table 12). Increased porosity along with high moisture content at the root zone of the crop might have resulted in poor aeration and reduced root growth. This might be the reason for decreased root volume at higher level of hydrogel @ 3.75 kg ha^{-1}. Decreased root volume with increase in the level of hydrogel might be due to less aeration and/or high moisture content (Table 6). Increased root growth due to hydrogel application was also observed by Zhang *et al.* (2005) in maize and Meena *et al.* (2011) in tomato.

Hydrogel @ 1.25 kg ha^{-1} +
rice straw mulch @ 5 t ha^{-1}

Hydrogel @ 2.5 kg ha^{-1} +
rice straw mulch @ 5 t ha^{-1}

Hydrogel @ 3.75 kg ha^{-1} +
rice straw mulch @ 5 t ha^{-1}

Control

Plate 2. Root volume at harvest

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5.2 EFFECT OF HYDROGEL AND MULCHING ON YIELD AND YIELD ATTRIBUTES OF MAIZE

5.2.1 Yield attributes

Yield is the net outcome of several interactions such as soil properties, weather parameters, leaf area and various metabolic and biochemical interactions taking place during crop growth.

The grain yield of maize was also influenced by dry matter accumulation in different parts especially in reproductive parts and yield components which is the product of interactions of above characters. The cause and effect relationship is difficult to understand mainly because of complexity in understanding the interplay of several processes and functions which ultimately led to changes not only in growth, development and physiology, but also on the yield, which is the most complex character. It was well established that the yield of the plant is decided by the growth parameters like LAI, number of leaves, root growth and dry matter production. The growth analysis technique has been adopted as one of the standard approaches in the absence of sophisticated instruments to analyse the structure of yield in several crops.

The important yield parameters which decides yield in maize are number of cobs plant^{-1}, number of grains cob^{-1} and test weight of grain. Number of grains cob^{-1} is decided by length and girth of cob. Results on length and girth of cob showed significant difference between control and remaining treatments (Table 7). Control recorded lower length and girth of the cob than the remaining treatments. This might be due to good availability of water and nutrients to the plants in hydrogel and mulch applied treatments resulted in better root and shoot growth, leaf area, LAI and dry matter production which finally reflected on the yield components and yield than the control. The increased length and girth of the cob due to straw mulch application was also observed by Khan and Parvej (2010) and Zhang *et al*. (2015).

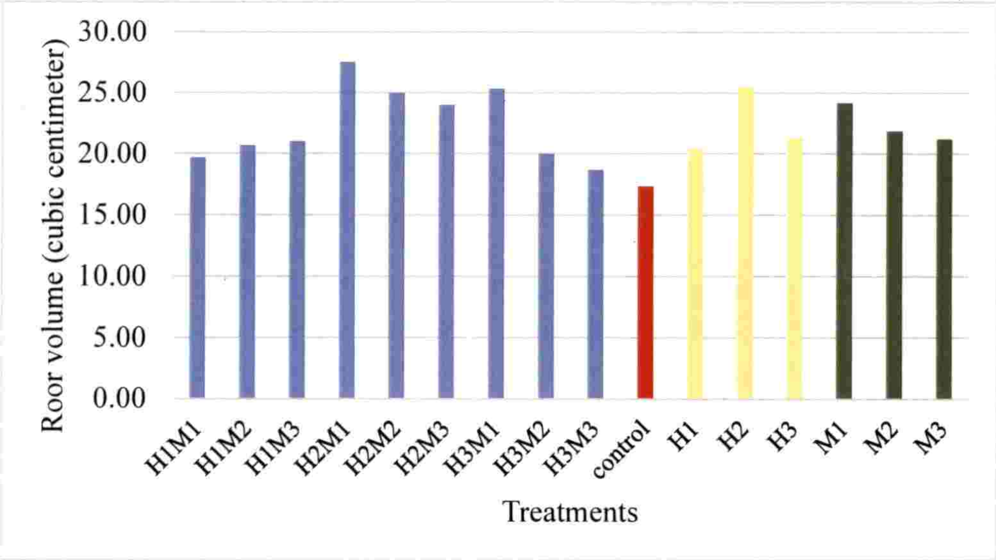

Fig. 5. Effect of hydrogel and mulch on root volume at harvest stage (cm^3)

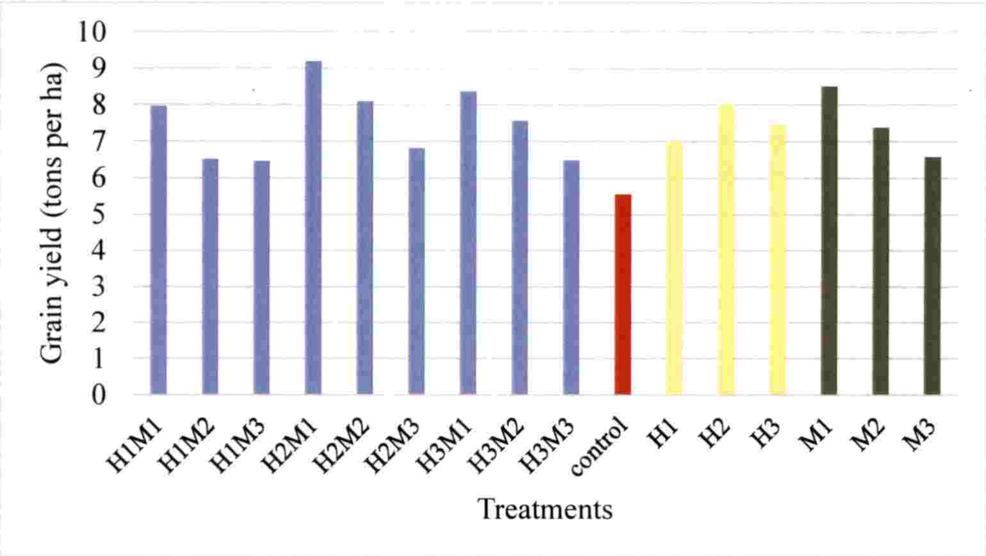

Fig. 6. Effect of hydrogel and mulch on grain yield (t ha^{-1})

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Hydrogel @ 1.25 kg ha^{-1} + rice straw mulch @ 5 t ha^{-1}

Hydrogel @ 2.5 kg ha^{-1} + rice straw mulch @ 5 t ha^{-1}

Hydrogel @ 3.75 kg ha^{-1} + rice straw mulch @ 5 t ha^{-1}

Control

Plate 3. Cobs after harvesting

Though, the genetic composition of a crop cultivar is the main component determining its yield potential, the expression of morphological, physiological and biochemical factors finally decides the productivity of a crop in moisture stress situation. Yield is a complex attribute which comprises the interaction of several intrinsic and exterior factors. It mostly depends upon the production and mobilization of carbohydrates, uptake of moisture and nutrients from soil, in additional to a number of environmental factors to which crop is exposed during the growth period (Schonfeld *et al.*, 1988).

Among hydrogel levels, maximum number of grains cob^{-1} was recorded in hydrogel applied @ 2.5 kg ha^{-1} and it was on par with hydrogel @ 3.75 kg ha^{-1}. Maximum number of grains cob^{-1} was recorded by rice straw mulch applied @ 5 t ha^{-1} and among interactions, rice straw mulch @ 5 t ha^{-1} with hydrogel @ 3.75 kg ha^{-1} produced maximum number of grains cob^{-1} and it was on par with application rice straw mulch @ 5 t ha^{-1} and hydrogel @ 2.5 kg ha^{-1}. Control produced lower number of grains cob^{-1} than the remaining treatments (Table 7). With respect to percentage increase in number of grains cob^{-1}, hydrogel @ 2.5 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1} recorded 22.01, 26.39 % respectively over control (Table 7). Among combinations, hydrogel @ 3.75 kg ha^{-1} with rice straw mulch @ 5 t ha^{-1} recorded 32.53 % more number of grains cob^{-1} than the control (Table 7). More number of grains cob^{-1} may be due to good pollination, better development of grains by increased availability of nutrients, water and high photosynthates accumulation. The increased number of grains cob^{-1} due to hydrogel application was also reported by Mazen *et al.* (2015) and Kumari *et al.* (2017). Nill and Nill (1993), Singh *et al.* (2015) and Zhang *et al.* (2015) also reported the positive effect of straw mulch on grains cob^{-1} in maize.

Among types of mulch, test weight (100 grains) was maximum in rice straw mulch applied @ 5 t ha^{-1}. Control recorded the lowest test weight when compared with remaining treatments (Table 8). Higher test weight might be due to high photosynthates accumulation and translocation to the grains. The higher test weight due to mulch application was by Khan and Parvej (2010), Singh *et al.* (2015) and Ma *et al.* (2017).

5.2.2 Yield of maize

Higher cob, grain (Fig. 6) and stover yield was observed with main and interaction effects of treatments with hydrogel @ 2.5 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1}. Control produced lower cob, grain and stover yield than the remaining treatments (Table 8). With respect to percentage increase in grain yield over control application of hydrogel @ 2.5 kg ha^{-1}, rice straw mulch @ 5 t ha^{-1} and their combination recorded 44.42, 53.06 and 65.29 % more root volume respectively than control (Table 8). The higher grain yield in these treatments might be attributed to more number of grains cob^{-1} (Table 7 and Table 8). The improvement in yield component was due to the improved growth parameters like higher total dry matter production and higher leaf area and LAI. Increased grain yield due to hydrogel application was also observed by Magalhaes *et al.* (1987), Yangyuoru *et al.* (2006) and Kumari *et al.* (2017) and due to mulching was observed by Gajri *et al.* (1994), Shen *et al.* (2012), Stagnari *et al.* (2014) and Zhang *et al.* (2015).

5.2.3 Harvest index

Harvest index reflects the partitioning of photosynthates between the grain and the vegetative portion of plant. It was significant in case of hydrogel application. Among the hydrogel levels hydrogel applied @ 3.75 kg ha^{-1} recorded maximum harvest index and was on par with hydrogel applied @ 2.5 kg ha^{-1}. Control recorded the lowest harvest index than the rest of the treatments (Table 8). This might be due to proper translocation of photo assimilates to the grains resulted in a stable individual grain weight. The higher harvest index due to hydrogel application was also observed by Yazdani *et al.* (2007) in soybean.

An increase in growth and yield attributes in the present experiment could be because of sufficient availability of water during the growth stages of the crop. Increased availability of water indirectly influences the nutrient supply by the super absorbent polymer to the plant under water stress condition, which in turn lead to better translocation of water, nutrients and photo assimilates and finally better plant growth, development and yield.

5.3 EFFECT OF HYDROGEL AND MULCHING ON PLANT ANALYSIS OF MAIZE

It can be seen from Table 10 that the nutrient uptake was significantly influenced by treatments. Among the different levels of hydrogel, application of hydrogel @ 2.5 kg ha^{-1} recorded the highest stover, grain and total N and P uptake. The highest K uptake by grain was recorded by application of hydrogel @ 2.5 kg ha^{-1}, while maximum stover and total K uptake was recorded in hydrogel @ 3.75 kg ha^{-1}.

Among types of mulch maximum stover, grain and total N, P, K uptake was recorded by application of rice straw mulch @ 5 t ha^{-1}. Among interactions, maximum total N and P uptake was recorded with hydrogel @ 2.5 kg ha^{-1} along with rice straw mulch applied @ 5t ha^{-1}. Maximum total K uptake was recorded in hydrogel @ 3.75 kg ha^{-1} with rice straw mulch applied @ 5 t ha^{-1}. Increased nutrient uptake in rice straw mulch and hydrogel applied plots might be due to increased availability of soil moisture content and root growth which inturn influence the nutrient uptake and high dry matter production. Increased nutrient uptake by hydrogel application was also observed by Mandal *et al.* (2015) in maize and Shahid *et al.* (2016) in wheat.

5.4 EFFECT OF HYDROGEL AND MULCHING ON SOIL ANALYSIS

5.4.1 Soil moisture content

Hydrogel, a substance that absorbs water and swells into several times of their original size and weight are used in soil to create a water reserve near the rhizosphere zone (Han *et al.*, 2010). The hydrogel application leads to increased WUE utilizing the moisture that would have been otherwise leached out beyond the root zone of the crop.

When, the hydrogel is added into the soil, they hold large amount of moisture and nutrients, which are released subsequently according to the requirement of the plant (Bhardwaj *et al.*, 2007). Mulching decreased the evaporation of soil water through shading soil surface from solar radiation (Bond and Willis, 1970) and this moisture will be available to plants for longer period of time. Results on effect of mulch (Table 11) showed a significant influence on soil moisture. Rice straw mulch @ 5 t ha^{-1} recorded maximum soil moisture content at 15 and 30 cm depth at all the stages of crop growth except at 60 DAS (Fig. 9 and 10). This might be due to better soil surface coverage offered by straw mulch than the other mulches resulted in reduced evaporation from the soil. The insignificant effect of different types of mulch on soil moisture at 15 cm depth at 60 DAS may be attributed to the shading effect of plant canopy on the soil surface. Hydrogel applied @ 3.75 kg ha^{-1} recorded maximum moisture content at 15 and 30 cm depth at all the stages of the crop growth except at harvest stage where hydrogel effect was non-significant and it was on par with hydrogel @ 2.5 kg ha^{-1} at 60 DAS (15 cm depth) (Table 11 and Fig. 7 and 8). In general, among the interactions the high soil moisture content at 15 and 30 cm depth was found with hydrogel @ 3.75 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1} at all the stages under observation (Fig. 11 and 12). High moisture content in hydrogel applied treatment @ 3.75 kg ha^{-1} was due to preservation of moisture by the hydrogel and slow release to the soil in accordance with decrease in the soil moisture content. At all the stages, control was recorded lower moisture content than the remaining treatments except at 60 DAS (30 cm depth). When comparing the percentage increase in soil moisture content at 30 cm depth with control it was observed that hydrogel application @ 3.75 kg ha^{-1} recorded 84.86 %, rice straw mulch application @ 5 t ha^{-1} recorded 82.16 % and their combination recorded 126.49 % more soil moisture than the control (Table 11).

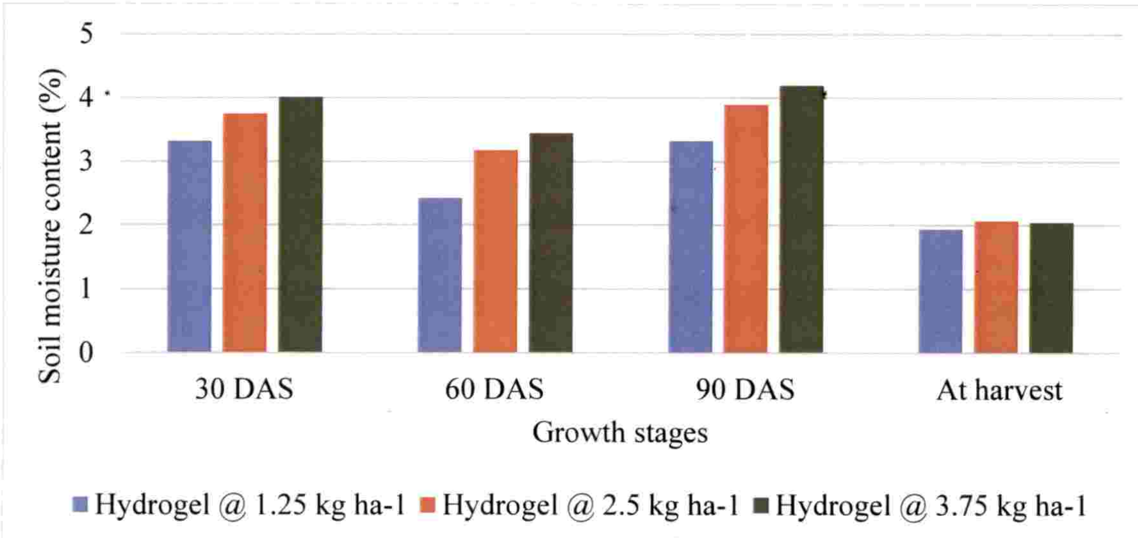

Fig. 7. Effect of hydrogel on soil moisture content (%) at 15 cm depth

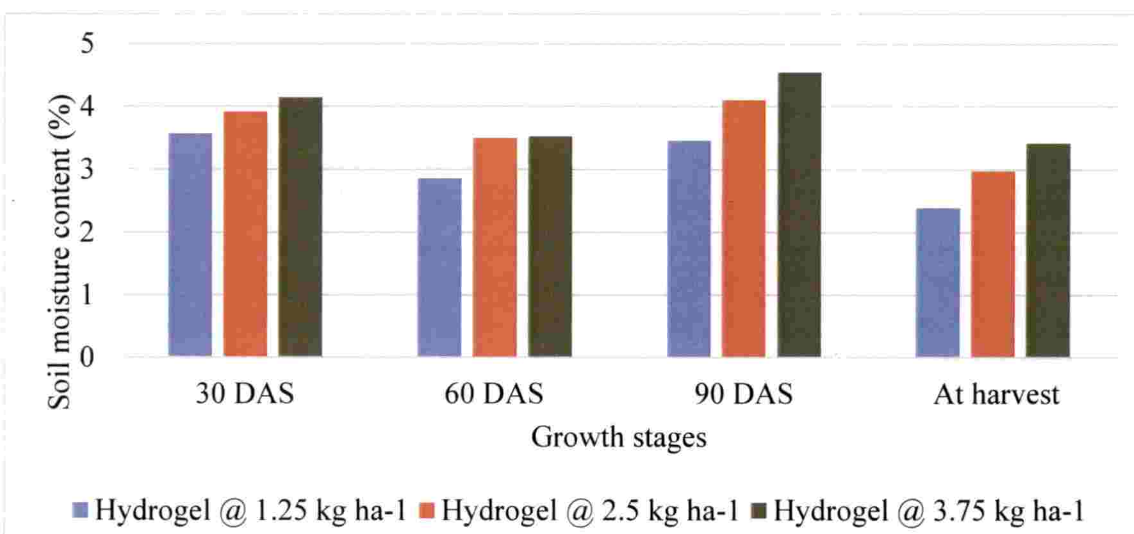

Fig. 8. Effect of hydrogel on soil moisture content (%) at 30 cm depth

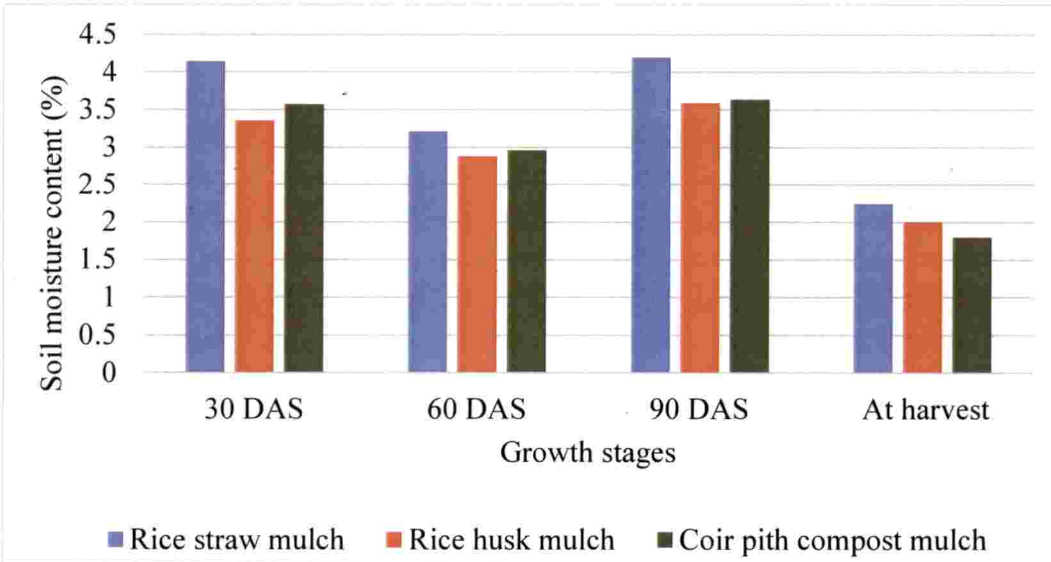

Fig. 9. Effect of mulch on soil moisture content (%) at 15 cm depth

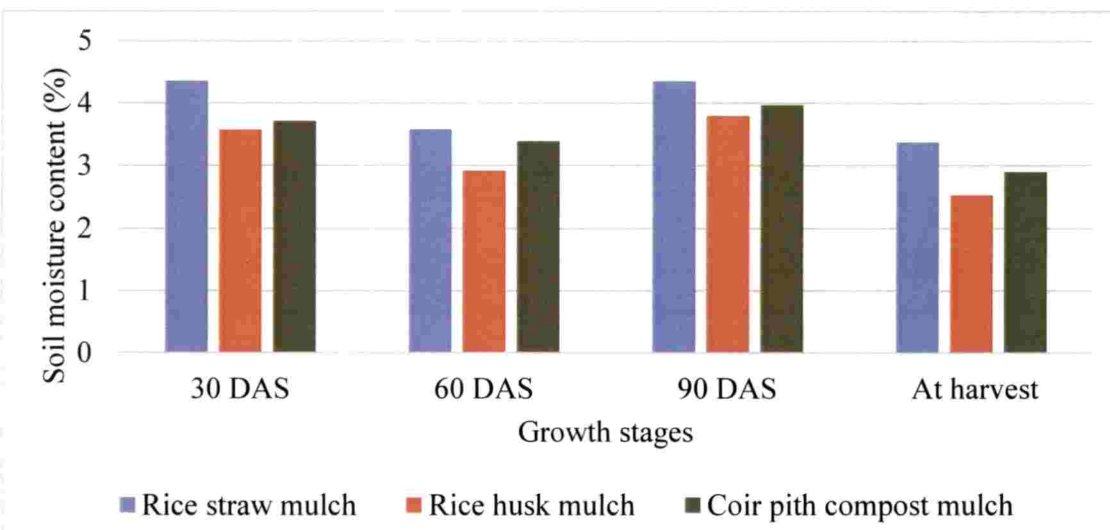

Fig. 10. Effect of mulch on soil moisture content (%) at 30 cm depth

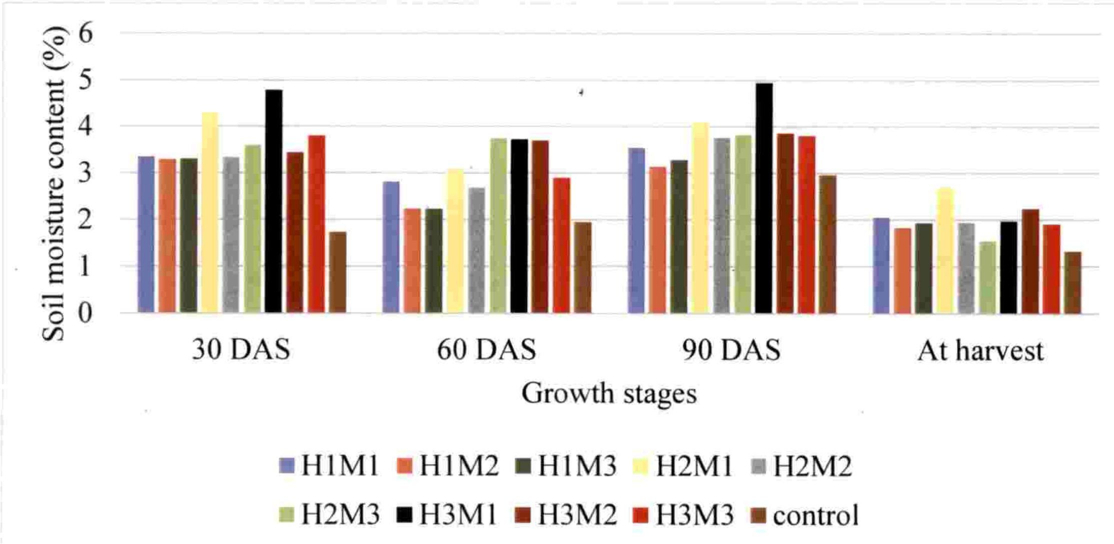

Fig. 11. Effect of hydrogel and mulch on soil moisture content (%) at 15 cm depth

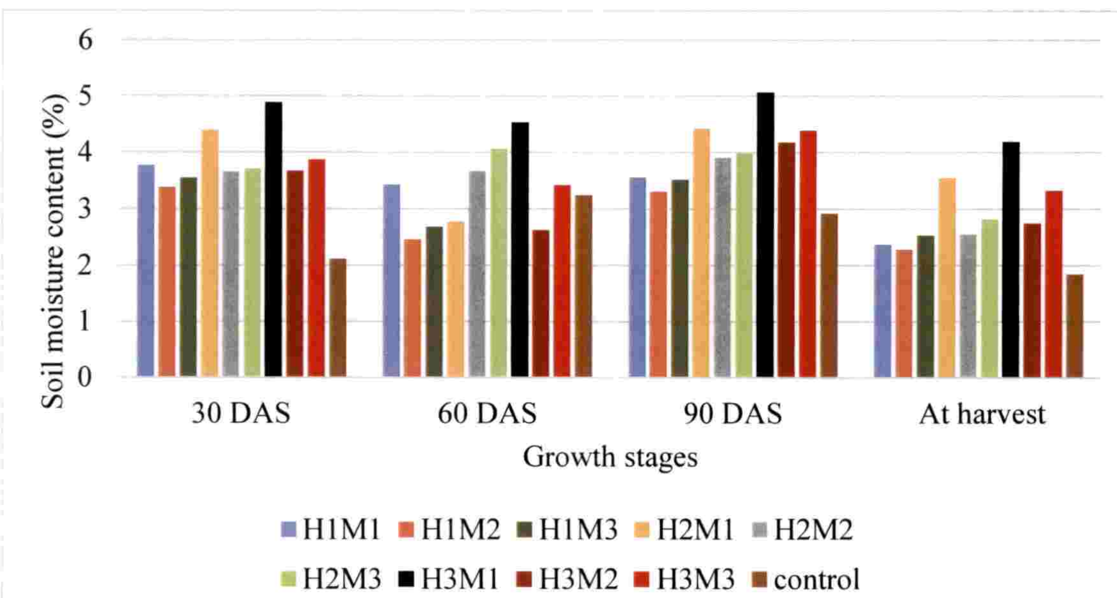

Fig. 12. Effect of hydrogel and mulch on soil moisture content (%) at 30 cm depth

Increased soil moisture content due to straw mulching was also observed by Shen *et al.* (2012), Li *et al.* (2013) and Zhao *et al.* (2014) and increased soil moisture content by hydrogel application was reported by Koupai *et al.* (2008), Ekabafe *et al.* (2011) and Nazarli *et al.* (2012) in sandy soil.

5.4.2 Soil physical properties

Among the types of mulch, coirpith compost mulch @ 2.5 t ha^{-1} shown the maximum porosity. Among the hydrogel levels, hydrogel applied @ 3.75 kg ha^{-1} recorded the maximum porosity (Table 12). Increase in the porosity of soil due to hydrogel application was observed by Uz *et al.* (2008) and due to mulching was observed by Uguru *et al.* (2015).

5.4.3 Soil chemical properties

Among the types of mulch, rice husk mulch @ 5 t ha^{-1} showed high content of available soil N, P_2O_5, K_2O than other types of mulch. Though rice husk is applied as a mulch, it will take more time to degrade due to wide C: N ratio and high silica content. Part of the applied nutrients and the nutrients available from the soil may be utilized for decomposition of rice husk and might be retained in the soil resulted in low uptake of these nutrients by the plants in rice husk mulch treatment. Among the levels of hydrogel, more available soil N and K_2O was recorded in plots where hydrogel was applied @ 1.25 kg ha^{-1} and more available soil P_2O_5 content was recorded in hydrogel applied @ 3.75 kg ha^{-1} (Table 12). High available soil N and K_2O content was recorded when hydrogel was applied @ 1.25 kg ha^{-1} with rice husk mulch @ 5 t ha^{-1} (Table 12) and high available soil P_2O_5 recorded when hydrogel was applied @ 3.75 kg ha^{-1} with rice husk mulch @ 5 t ha^{-1}. Hydrogels usually contain micro pores that allow small molecules such as NH_4 to diffuse through the hydrogel. The subsequent release of nutrient is then based on the diffusive properties of the polymer, its decomposition rate, and the nature of the nutrient salt (Johnson and Veltkamp, 1985). Control recorded high available soil N, P_2O_5, K_2O content than the remaining treatments because less uptake of these nutrients in control plot attributed to poor growth of the plant.

5.5 EFFECT OF HYDROGEL AND MULCHING ON ECONOMICS OF MAIZE CULIVATION

Economic analysis is the most important parameter to know the monetary benefits and losses in crop husbandry. Present experiment showed (Table 13) that among types of mulch, maximum gross income and net income was obtained in rice straw mulch applied @ 5 t ha^{-1} due to high yield. Maximum BCR was observed in rice husk mulch applied @ 5 t ha^{-1} due to low cost of rice husk than other two types of mulch. Among types of hydrogel, maximum gross income, net income and BCR was observed in which hydrogel was applied @ 2.5 kg ha^{-1} due to high yield obtained in this level of hydrogel. Among interaction effects maximum net income and gross income was obtained in hydrogel applied @ 2.5 kg ha^{-1} with rice straw mulch @ 5 t ha^{-1} due to high yield. Maximum BCR (Fig. 13) was recorded with the interaction of hydrogel @ 2.5 kg ha^{-1} and rice husk mulch @ 5 t ha^{-1} because of low cost of rice husk than the other two types of mulch. When compared the control with rest of treatments, control recorded lower gross income, net income and BCR than the remaining treatments due to less yield in control plot than the other treatments.

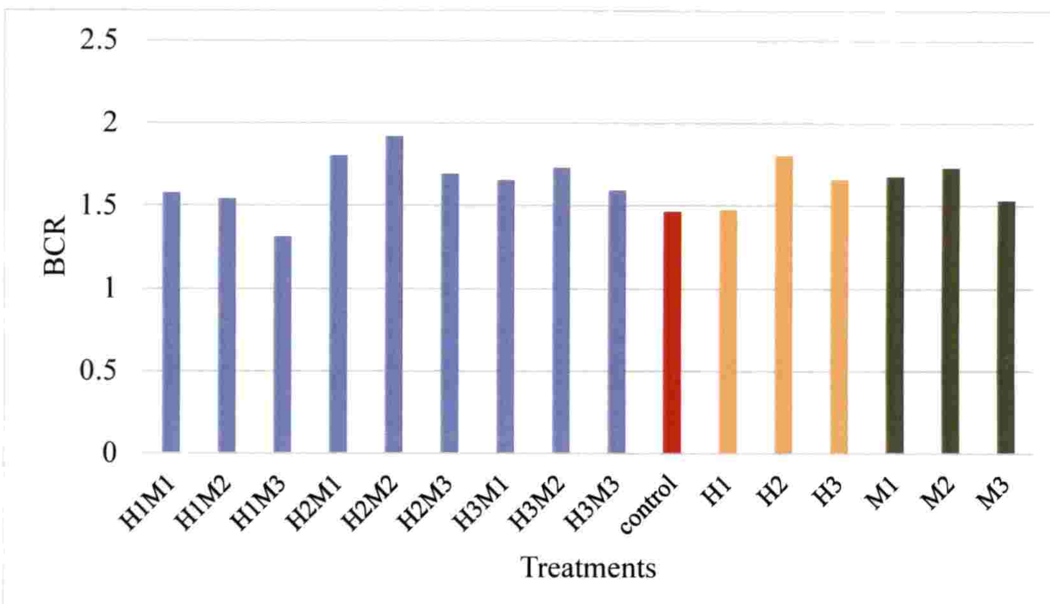

Fig. 13. Effect of hydrogel and mulch on BCR

SUMMARY

6. SUMMARY

A field experiment entitled "Effect of hydrogel and mulching on maize (*Zea mays* L.) in sandy soil" was carried out at College of Agriculture, Padannakkad during 2016-2018 to study the effect of hydrogel (super absorbent polymer) and mulching on soil moisture status, growth and yield of maize in sandy soil. Soil of experimental field is sandy. The experiment was laid out in factorial randomized block design having two factors with three levels each and one additional control. Hydrogel and mulch were the two factors. Three levels of hydrogel were H_1 - 1.25 kg ha^{-1}, H_2 - 2.5 kg ha^{-1}, H_3 - 3.75 kg ha^{-1} and three types of mulch were M_1 – rice straw, M_2 – rice husk, M_3 – Coir pith compost were tested in the study. The treatment combinations were T_1 - 1.25 kg ha^{-1} hydrogel + rice straw, T_2 - 1.25 kg ha^{-1} hydrogel + rice husk, T_3 - 1.25 kg ha^{-1} hydrogel + Coir pith compost, T_4 - 2.5 kg ha^{-1} hydrogel + rice straw, T_5 - 2.5 kg ha^{-1} hydrogel + rice husk, T_6 - 2.5 kg ha^{-1} hydrogel + coir pith compost, T_7 - 3.75 kg ha^{-1} hydrogel + rice straw, T_8 - 3.75 kg ha^{-1} hydrogel + rice husk, T_9 - 3.75 kg ha^{-1} hydrogel + coir pith compost, T_{10} - control (KAU Package of Practices recommendations, 2016).

Straw mulch and rice husk mulch were applied @ 5 t ha^{-1} and coir pith compost mulch was applied @ 2.5 t ha^{-1}. Observations were recorded on Growth and growth attributes such as plant height at 30, 60, 90 DAS and harvesting stage, number of leaves per plant at 30, 60, 90 DAS and harvesting stage, leaf area and Leaf Area Index (LAI) at 30, 60, 90 DAS and harvesting stage, dry matter production at 30, 60, 90 DAS and harvesting stage, root volume at harvest and RLWC at 30, 60 and 90 DAS. The yield and yield attributes like number of cobs $plant^{-1}$, number of rows cob^{-1}, length of cob, girth of cob, number of grains cob^{-1}, test weight (100 grains), cob yield, grain yield, stover yield and harvest index were recorded at harvest stage.

Plant analysis like nutrient content of plant (N, P, K) and nutrient uptake (N, P, K) and soil analysis like moisture content at sowing, 30, 60, 90 DAS and at harvest (15 cm and 30 cm depth), nutrient status of soil before sowing and at harvest, bulk density of soil before sowing and at harvest, porosity of soil before sowing and at harvest were also recorded. Economics like Gross return, Net return, Benefit: Cost ratio (BCR) were worked out based on existing local market price of inputs and produce. The data were statistically analysed and results of the study were briefly presented here under.

At initial stages (30 DAS) of the maize crop, among levels of hydrogel, hydrogel applied @ 2.5 kg ha^{-1} recorded maximum plant height. Among the types of mulch, rice straw mulch @ 5 t ha^{-1} showed the maximum plant height of the maize at 30 and 60 DAS. Among the Interactions hydrogel @ 2.5 kg ha^{-1} with rice straw mulch @ 5 t ha^{-1} recorded the maximum plant height at 30 DAS. At 30 and 60 DAS all the treatments recorded the higher height than the control.

Number of leaves $plant^{-1}$ was significantly influenced by the rice straw mulch @ 5 t ha^{-1} at 60 and 90 DAS. At 30 and 90 DAS, all treatments showed more number of leaves than the control.

Maximum leaf area and LAI was observed in treatments with hydrogel @ 3.75 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1} and its combinations at all the stages (30, 60 and 90 DAS) which was on par with H_2M_1 at 60 and 90 DAS and with H_1M_1 at 90 DAS. Control recorded a lower leaf area and LAI than the remaining treatments.

Effect of hydrogel on dry matter production was significant at 30, 60 DAS and at harvest stage. Hydrogel applied @ 3.75 kg ha^{-1} showed the maximum dry matter production at 30 and 60 DAS but at harvest stage hydrogel applied @ 2.5 kg ha^{-1} recorded the maximum dry matter production and was on par with hydrogel applied @ 3.75 kg ha^{-1}. Rice straw mulch @ 5 t ha^{-1} showed maximum dry matter production at 30, 60, 90 and at harvest stage. Among the interactions, hydrogel @ 3.75 kg ha^{-1} with rice straw mulch @ 5 t ha^{-1} recorded maximum dry matter production at 30 and 60 DAS but at 90 and harvest stage hydrogel @ 2.5 kg ha^{-1} with rice straw mulch @ 5 t ha^{-1} gave maximum dry matter production and it was on par with H_3M_1 and H_3M_1 at 90 DAS. At all the stages of crop, control recorded lower dry matter production than the remaining treatments.

The results on root volume of maize plant was found maximum with the main effects and interaction effects of hydrogel application @ 2.5 kg ha^{-1} and rice straw mulch application @ 5 t ha^{-1} which was on par with hydrogel @ 3.75 kg ha^{-1} with rice straw mulch @ 5 t ha^{-1}. Control showed a lower root volume than the other treatments.

Results on length and girth of cob showed significant difference between control and remaining treatments. Control showed a lower length and girth of the cob than the rest of treatments.

Maximum number of grains cob^{-1} was observed in hydrogel application @ 2.5 kg ha^{-1} and was on par with hydrogel @ 3.75 kg ha^{-1}. Maximum number of grains cob^{-1} was recorded by rice straw mulch applied @ 5 t ha^{-1} and among interactions hydrogel @ 3.75 kg ha^{-1} with rice straw mulch @ 5 t ha^{-1} was produced maximum number of grains cob^{-1} and it was on par with hydrogel @ 2.5 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1}. Control produced lower number of grains cob^{-1} than the remaining treatments.

Application of rice straw mulch @ 5 t ha^{-1} recorded highest test weight and control recorded lowest test weight than the remaining treatments.

Higher cob, grain and stover yield were observed in main and interaction effects of treatments with hydrogel @ 2.5 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1}. Control produced lower cob, grain and stover yield than the remaining treatments.

Harvest index was significant in case of hydrogel application. Hydrogel applied @ 3.75 kg ha^{-1} recorded maximum harvest index and was on par with hydrogel applied @ 2.5 kg ha^{-1}. Control produced lower harvest index than the rest of the treatments.

Application of hydrogel @ 2.5 kg ha^{-1} recorded the highest stover, grain and total N and P uptake. The highest K uptake by grain was recorded by application of hydrogel @ 2.5 kg ha^{-1}, while maximum stover and total K uptake was recorded in hydrogel @ 3.75 kg ha^{-1}. Among types of mulch maximum stover, grain and total N, P, K uptake was recorded by the application of rice straw mulch @ 5 t ha^{-1}. Among interactions, maximum total N and P uptake was recorded in which hydrogel @ 2.5 kg ha^{-1} with rice straw mulch @ 5 t ha^{-1} and maximum total K uptake was recorded in hydrogel @ 3.75 kg ha^{-1} with rice straw mulch applied @ 5 t ha^{-1}.

With regards to moisture content of soil, rice straw mulch @ 5 t ha^{-1} recorded maximum soil moisture content (15 and 30 cm depth) at all the stages of crop growth except at 60 DAS (15 cm depth). At 60 DAS, there was no significant difference between types of mulch on soil moisture at 15 cm depth. Hydrogel applied @ 3.75 kg ha^{-1} recorded maximum moisture content at 15 and 30 cm depth at all the stages of the crop growth except at harvest stage where hydrogel effect was non-significant and was on par with hydrogel @ 2.5 kg ha^{-1} at 60 DAS (15 cm depth).

In general, among the interactions, high soil moisture content at 15 and 30 cm depth was found with hydrogel @ 3.75 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1} at all the stages under observation. Control recorded lower moisture content than the remaining treatments at all the stages, except at 60 DAS (30 cm depth).

Hydrogel and mulch showed the significant effect on available soil N, P_2O_5, K_2O content. Among the types of mulch, rice husk mulch @ 5 t ha^{-1} recorded the high available soil N, P_2O_5, K_2O content than other types of mulch. Among the levels of hydrogel, high available soil N and K_2O was recorded in which hydrogel applied @ 1.25 kg ha^{-1} and high available soil P_2O_5 content was recorded in which hydrogel applied @ 3.75 kg ha^{-1}. Among the interactions, high available soil N and K_2O content was recorded in which hydrogel applied @ 1.25 kg ha^{-1} with rice husk mulch @ 5 t ha^{-1} and maximum available P_2O_5 content was recorded with H_3M_2.

Control recorded the high available soil N, P_2O_5, K_2O content than the remaining treatments.

Hydrogel and mulch showed a significant effect on porosity of soil. Coirpith compost mulch @ 2.5 t ha^{-1} and hydrogel applied @ 3.75 kg ha^{-1} recorded the maximum porosity.

Hydrogel and mulch showed the significant effect on economics of experiment. Among types of mulch, maximum gross income and net income was obtained in rice straw mulch applied @ 5 t ha^{-1} and maximum BCR was recorded in rice husk mulch was applied @ 5 t ha^{-1}. Among types of hydrogel, maximum gross income, net income and BCR was observed in which hydrogel applied @ 2.5 kg ha^{-1}. Among interaction effects maximum net income and gross income were recorded when hydrogel applied @ 2.5 kg ha^{-1} with rice straw mulch @ 5 t ha^{-1} and maximum BCR recorded with the interaction of hydrogel @ 2.5 kg ha^{-1} and rice husk mulch @ 5 t ha^{-1}. When compared the control with rest of treatments, control recorded lower gross income, net income and BCR than the remaining treatments.

The overall results of the study revealed that in sandy soils, maize yield can be significantly improved by the application of hydrogel and mulch. The hydrogel @ 2.5 kg ha^{-1} in combination with rice straw mulch @ 5 t ha^{-1} was most efficient and economical and can be recommended for maize cultivation in sandy soils of Kerala.

Future line of work

Water management studies on maize under varying levels and methods of irrigation with different levels of hydrogel and rice straw mulch @ 5 t ha^{-1} in sandy soil offers a tremendous scope in future. There are possibilities to study the nutrient management practices with hydrogel and mulching on maize. More crops especially vegetables and ornamentals shall be included in such trials with hydrogel and rice straw mulch in sandy soils.

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7. REFERENCES

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APPENDIX

Appendix I. Weather parameters during the crop period in standard weeks

Standard week	Temperature (^{o}C)		Relative humidity (%)	BSS (hours)	Rainfall (mm)	Evaporation (mm)
	Maximum	Minimum				
45 (Nov 5 - 11)	31.43	21.56	80.86	2.03	0.00	3.49
46 (Nov 12 - 18)	31.29	20.57	78.21	1.83	0.00	3.40
47 (Nov 19 - 25)	31.53	22.36	79.50	2.13	0.00	2.99
48 (Nov 26 - Dec 2)	32.33	21.40	79.14	1.47	21.50	3.04
49 (Dec 3 - 9)	31.29	21.86	82.29	2.26	9.00	3.54
50(Dec 10 - 16)	30.90	21.86	81.36	4.17	0.00	2.91
51 (Dec 17 - 23)	32.14	19.11	72.21	9.84	0.00	3.60
52 (Dec 24 - 31)	31.69	17.75	71.81	9.71	0.00	3.56
1 (Jan 1 - 7)	31.16	19.00	77.71	8.96	0.00	3.64
2 (Jan 8 - 14)	31.07	20.61	78.43	7.96	0.00	3.41
3 (Jan 15 - 21)	31.39	19.36	76.00	8.24	0.00	3.44
4 (Jan 22 - 28)	30.64	21.30	77.86	7.54	0.00	3.93
5 (Jan 29 - Feb 4)	30.93	18.93	75.93	9.31	0.00	3.91
6 (Feb 5 - 11)	31.57	21.64	75.36	7.00	0.00	3.93
7 (Feb 12 - 18)	31.43	22.14	76.36	8.19	0.00	3.94
8 (Feb 19 - 25)	32.04	21.50	76.64	9.51	0.00	4.26
9 (Feb 26 - Mar 4)	32.29	21.50	75.14	9.49	0.00	4.51

ABSTRACT

EFFECT OF HYDROGEL AND MULCHING ON MAIZE (*Zea mays* L.) IN SANDY SOIL

by

RAJAP SHIVA KUMAR

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ABSTARCT

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ABSTRACT

An investigation entitled "Effect of hydrogel and mulching on maize (*Zea mays* L.) in sandy soil" was carried out at College of Agriculture, Padannakkad during 2016-2018 to study the effect of hydrogel (super absorbent polymer) and mulching on soil moisture status, growth and yield of maize in sandy soil. The experiment was laid out in factorial randomized block design with three replications. The treatment combinations included three levels of hydrogel *viz.* H_1 – 1.25 kg ha^{-1}, H_2 – 2.5 kg ha^{-1}, H_3 – 3.75 kg ha^{-1} and three types of mulch *viz.* M_1 – rice straw (5 t ha^{-1}), M_2 – rice husk (5 t ha^{-1}), M_3 – coirpith compost (2.5 t ha^{-1}) and one control (KAU Package of Practices recommendations). Observations were recorded on growth and growth attributes, yield and yield attributes, plant analysis, soil analysis and economics.

Hydrogel @ 2.5 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1} recorded maximum plant height, dry matter production and root volume of maize whereas maximum leaf area and LAI were observed in hydrogel @ 3.75 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1}.

The yield and yield parameters such as cob, grain and stover yield were found to be higher in treatments receiving hydrogel @ 2.5 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1} than other levels of hydrogel and types of mulch.

The response of hydrogel @ 2.5 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1} was significantly superior over other treatments with respect to total N and P uptake. While total K uptake recorded was maximum in the case of hydrogel @ 3.75 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1}.

The major beneficial effect of hydrogel was in enhancing and maintaining soil moisture status of coarse textured sandy soil at 15 and 30 cm depth. The treatment receiving hydrogel @ 3.75 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1} recorded maximum soil moisture retention. The maximum porosity was recorded in the case of hydrogel @ 3.75 kg ha^{-1} and coirpith compost mulch @ 2.5 t ha^{-1}.

The residual nutrient status with respect to available N and K_2O recorded maximum values in hydrogel @ 1.25 kg ha^{-1} and rice husk mulch @ 5 t ha^{-1} and

available P_2O_5 was maximum with hydrogel @ 3.75 kg ha^{-1} and rice husk mulch @ 5 t ha^{-1}.

Considering the economics of maize crop production, the gross and net income obtained were maximum in hydrogel @ 2.5 kg ha^{-1} and rice straw mulch @ 5 t ha^{-1}. However, BCR was found to be maximum in treatment with hydrogel @ 2.5 kg ha^{-1} and rice husk mulch @ 5 t ha^{-1}.

The maize growth and yield were significantly improved by the application of hydrogel and different mulches. Hydrogel @ 2.5 kg ha^{-1} in combination with rice straw mulch @ 5 t ha^{-1} was most efficient and economical compared to other combinations and can be recommended for maize cultivation in sandy soils of Kerala.