RESEARCH ARTICLE

# Humic acid and Hydrogel Influence on Maize Productivity and Soil Fertility of Alfisols

Kasthuri Rajamani[1]*, K. Indudhar Reddy[2] and A. Srinivas[1]

[1]Regional Agricultural Research Station, Professor Jayashankar Telangana State Agricultural University, Palem, Nagarkurnool, Telangana, India

[2]Agro Climate Research Centre, Professor Jayashankar Telangana State Agricultural University, ARI, Rajendranagar, Hyderabad, Telangana, India

## ABSTRACT

*A field study was carried out to study the performance of superabsorbent polymer at 2.5 and 4.5 kg ha-1 and humic acid at 15 and 30 kg ha-1 alone and their combinations with 100% RDF on yield, bulk density, soil moisture content, relative water content and soil chemical parameters (pH, EC, OC, N, P2O5 and K2O) of maize grown alfisols under rainfed conditions at Regional Agricultural Research Station, Palem, Telangana. Conjoint application of hydrogel @ 4.5 kg ha-1 + humic acid @ 30 kg ha-1 along with 100% RDF package significantly increased the pooled grain and stover yield (7136 and 8457 kg ha-1) of maize. The bulk density (g cm-3) of the soil not influenced significantly among the different combinations of humic acid and hydrogel with 100% recommended dose of maize fertilizers. However, the soil moisture content (%) exerted significantly as 19.95 & 21.53 and 20.66 and 21.69% as compared to that of 100% RDF (12.28 & 13.96 and 13.09 & 14.12%) at tasseling and dough stages in both the years and similar results were observed with relative water content (%). The pooled soil pH, EC and OC were not shown any significant difference among the treatments over control values. Irrespective of hydrogel and humic acid combinations with 100% RDF increased the available macronutrient (N, P2O5 & K2O) status as 179.30, 72.88 and 391.01 kg ha-1 over control treatment (147.88, 56.33 and 362.11 kg ha-1). This examination demonstrated positive interaction of humic acid with super absorbent polymer to improve maize productivity and soil fertility status in drylands.*

**Keywords:** *Super absorbent polymer, humic acid, hydrogel, recommended dose of fertilizer, bulk density, soil moisture content and maize*

## INTRODUCTION

Maize is a multipurpose crop with great nutritional values, which contains about 72% starch, 10.4% proteins, and 4.5% fats, minerals, and non-cholesterol oil [1] and leads the third cereal crop of the world after wheat and rice. In India, the crop is grown more than 76.03 lakh hectares under rainfed conditions (Agricultural Market Intelligence Centre, PJTSAU, 2021) with an erratic distribution of rainfall, dry spells, poor-quality seed and imbalanced nutrients application lead to a reduction in crop yields in developing countries [2]. The widespread use of unsustainable production techniques in agricultural systems has resulted in extensive deterioration of soil quality and reductions in soil organic matter content and crop production [3]. Indian soils generally have low organic matter and are commonly applied with chemical fertilizers that may improve yield in short term, but do not enhance the physical properties of the soil, and result in soil degradation over the longer term. Organic materials are important soil additives to improve soil physical, chemical and biological properties. The usage of organic-based materials has gained importance to sustain productivity, particularly in semi-arid regions to prevent soil degradation [4].



Citation: Kasthuri Rajamani, K. Indudhar Reddy and A. Srinivas (2021). Humic acid and Hydrogel Influence on Maize Productivity and Soil Fertility of Alfisols. *Chemical Engineering*. v02i03, 33-40. http://dx.doi.org/10.53709/ CHE.2021.v02i02.007

**DOI:**
http://dx.doi.org/10.53709/CHE.2021.v02i02.007

**Corresponding Author:**
Kasthuri Rajamani
kasthuri.agrico114@gmail.com

**Received on:** April 22, 2021
**Revised on:** May 30, 2021
**Accepted on:** : June 19, 2021

Certain components of organic sources such as polysaccharides, humic substances, root material and fungal hyphae have an important role to improve soil physical and chemical properties, and were also enhanced with the application of poly-acrylamides and polyvinyl alcohols [5] at lower rates.

Humic acids and their components are water-soluble, derived from coal and other natural sources, which have modes of action similar to synthetic conditioners, have been evaluated as potential soil conditioners to provide numerous benefits to crop production [6]. Humic acid enhances cell permeability, microbial growth and activities, soil physical properties, nutrient uptake, and stimulates photosynthetic efficiency due to decomposition of animal and plant residues [7] at rhizosphere. These materials regulate several metabolic, hormonal, biochemical, molecular, and physiological activities to trigger different biotic and abiotic stresses [8]. Around 1 kg $ha^{-1}$ of humic acid may improve the yield of several crops and soil physio-chemical attributes up to 20% [9]. However, these improvements are more dependent on the source, concentration, and molecular weight of humic substance application [10]. Many authors have highlighted the production advantages of humic acid application on various crops [11-12], and improves moisture retention and mitigation of salinity [13].

Efficient management practices were needed for productive use of limited moisture during crop growing season especially at critical growth stages, where the nutrient imbalances restrict the crop average productivity. Systematic irrigation water management operations have an enormous impact on applied inputs, besides effective irrigation water management, improved rainwater and soil moisture conservation, especially in drylands. Under deficit water availability, recent water management techniques, *viz.,* precise irrigation scheduling, fertigation, and use of superabsorbent polymers with high water holding capacity, bio-compatibility, and synthetic flexibility raise new hopes to enhance crop productivity and water use efficiency under declining water resources in Alfisols [14]. The successful cultivation of different crops in semi-arid areas mainly dependent on conserved soil moisture, and superabsorbent polymers (hydrogels) may be of high significance. Under limited irrigation water availability, the use of synthetic polymers improves water availability to plants by restricting the drainage of water beyond the root zones [15]. These polymers absorb the conserved rain and other moisture, release it gradually at later stages to meet the water requirement of the crop, and also prolong the irrigation interval [16]. The hydrogels reduce nutrient losses by preventing leaching, especially nitrogen and potassium, thus promoting synchrony in nutrient release and uptake of nutrients as needed by crop plants [17]. The improvement in seed germination and seedling's survival arise higher biomass production to boost yields with the use of polymers [18]. Hydrogel remains safe and non-toxic and eventually decomposes to carbon dioxide, water, and ammonium and potassium ions, without any residue [19]. With this background, the present work aims to determine the integrated effect of humic acid and hydrogel on maize productivity, and soil fertility status of Alfisols under semi-arid conditions.

## MATERIAL AND METHODS

A field experiment was conducted at Regional Agricultural Research Station of Professor Jayashankar Telangana State Agricultural University, Palem, Telangana state, India during *kharif,* 2015 and 2016, where station was located in a rainfed area. The objective of the research was to find out the effect of conjoint application of hydrogel and humic acid on maize yield and nutrient status in Alfisols. The characteristics of the soils at the experimental site was sandy loam in texture, slightly alkaline (pH 7.61) in reaction, non-saline (0.27 dS $m^{-1}$), low in organic carbon (0.44 percent), available N (159.61 kg $ha^{-1}$), high in available $P_2O_5$ (61.38 kg $ha^{-1}$) and medium in $K_2O$ (317.21 kg $ha^{-1}$). The experiment was laid out in a randomized block design with ten treatments replicated three times. The maize hybrid DHM 117 was used as test crop by imposing treatments as follows: $T_1$: 100% RDF, $T_2$:100% RDF + Humic acid 15 kg $ha^{-1}$, $T_3$:100% RDF + Humic acid 30 kg $ha^{-1}$, $T_4$: 100% RDF + Hydrogel 2.5 kg $ha^{-1}$, $T_5$:100% RDF + Hydrogel 4.5 kg $ha^{-1}$, $T_6$:100% RDF + Humic acid 15 + Hydrogel 2.5 kg $ha^{-1}$, $T_7$:100% RDF + Humic acid 15 + Hydrogel 4.5 kg $ha^{-1}$, $T_8$:100% RDF + Humic acid 30 + Hydrogel 2.5 kg $ha^{-1}$, $T_9$:100% RDF + Humic acid 30 + Hydrogel 4.5 kg $ha^{-1}$. All the treatments received a uniform recommended dose of fertilizers *i.e.,* 200 kg N, 60 kg $P_2O_5$and 50

 http://dx.doi.org/10.53709/CHE.2021.v02i02.007

**Table 1:** Influence of different levels of Hydrogel and Humic acid on maize grain and stover yield (kg ha$^{-1}$)

| Treatments | 2015 | | 2016 | | Pooled | |
|---|---|---|---|---|---|---|
| | Grain Yield | Straw Yield | Grain Yield | Straw Yield | Grain Yield | Straw Yield |
| | (Kg ha$^{-1}$) | | | | | |
| $T_1$: 100% RDF | 6022 | 7028 | 6319 | 7216 | 6171 | 7122 |
| $T_2$: 100% RDF + Humic acid 15 kg ha$^{-1}$ | 6205 | 7332 | 6583 | 7520 | 6394 | 7426 |
| $T_3$: 100% RDF + Humic acid 30 kg ha$^{-1}$ | 6313 | 7521 | 6602 | 7709 | 6458 | 7615 |
| $T_4$: 100% RDF + Hydrogel 2.5 kg ha$^{-1}$ | 6361 | 7496 | 6674 | 7684 | 6518 | 7590 |
| $T_5$: 100% RDF + Hydrogel 4.5 kg ha$^{-1}$ | 6484 | 7584 | 6711 | 7772 | 6598 | 7678 |
| $T_6$: 100% RDF + Humic acid 15 kg ha$^{-1}$ + Hydrogel 2.5 kg ha$^{-1}$ | 6653 | 7962 | 6948 | 8150 | 6801 | 8056 |
| $T_7$: 100% RDF + Humic acid 15 kg ha$^{-1}$ + Hydrogel 4.5 kg ha$^{-1}$ | 6875 | 8101 | 7152 | 8289 | 7014 | 8195 |
| $T_8$: 100% RDF + Humic acid 30 kg ha$^{-1}$ + Hydrogel 2.5 kg ha$^{-1}$ | 6891 | 8139 | 7186 | 8327 | 7039 | 8233 |
| $T_9$: 100% RDF + Humic acid 30 kg ha$^{-1}$ + Hydrogel 4.5 kg ha$^{-1}$ | 6977 | 8363 | 7294 | 8551 | 7136 | 8457 |
| $T_{10}$: Control | 4458 | 5158 | 4731 | 5346 | 4595 | 5252 |
| SEm (+) | 16.30 | 33.07 | 10.52 | 21.38 | 14.69 | 28.51 |
| CD ( P = 0.05) | 51.73 | 87.21 | 27.39 | 60.14 | 39.05 | 73.29 |

**Table 2:** Influence of different levels of Hydrogel and Humic acid on soil Bulk density (g cm$^{-3}$) at harvest

| Treatments | Bulk Density (g cm$^{-3}$) | |
|---|---|---|
| | 2015 | 2016 |
| $T_1$: 100% RDF | 1.46 | 1.45 |
| $T_2$: 100% RDF + Humic acid 15 kg ha$^{-1}$ | 1.46 | 1.45 |
| $T_3$: 100% RDF + Humic acid 30 kg ha$^{-1}$ | 1.45 | 1.44 |
| $T_4$: 100% RDF + Hydrogel 2.5 kg ha$^{-1}$ | 1.46 | 1.45 |
| $T_5$: 100% RDF + Hydrogel 4.5 kg ha$^{-1}$ | 1.46 | 1.45 |
| $T_6$: 100% RDF + Humic acid 15 kg ha$^{-1}$ + Hydrogel 2.5 kg ha-1 | 1.46 | 1.45 |
| $T_7$: 100% RDF + Humic acid 15 kg ha$^{-1}$ + Hydrogel 4.5 kg ha-1 | 1.45 | 1.44 |
| T8: 100% RDF + Humic acid 30 kg ha$^{-1}$ + Hydrogel 2.5 kg ha-1 | 1.45 | 1.44 |
| $T_9$: 100% RDF + Humic acid 30 kg ha$^{-1}$ + Hydrogel 4.5 kg ha-1 | 1.45 | 1.44 |
| $T_{10}$: Control | 1.47 | 1.46 |
| SEm (+) | 0.005 | 0.003 |
| CD ( P = 0.05) | NS | NS |

**Table 3:** Influence of different levels of Hydrogel and Humic acid on pooled physico-chemical parameters of soil at harvest

| Treatments | pH | EC (dSm$^{-1}$) | OC (%) |
|---|---|---|---|
| $T_1$: 100% RDF | 7.41 | 0.14 | 0.42 |
| $T_2$: 100% RDF + Humic acid 15 kg ha$^{-1}$ | 7.39 | 0.12 | 0.43 |
| $T_3$: 100% RDF + Humic acid 30 kg ha$^{-1}$ | 7.38 | 0.11 | 0.43 |
| $T_4$: 100% RDF + Hydrogel 2.5 kg ha$^{-1}$ | 7.4 | 0.13 | 0.42 |
| $T_5$: 100% RDF + Hydrogel 4.5 kg ha$^{-1}$ | 7.40 | 0.13 | 0.42 |
| $T_6$: 100% RDF + Humic acid 15 kg ha$^{-1}$ + Hydrogel 2.5 kg ha-1 | 7.39 | 0.12 | 0.43 |
| $T_7$: 100% RDF + Humic acid 15 kg ha$^{-1}$ + Hydrogel 4.5 kg ha-1 | 7.38 | 0.11 | 0.43 |
| T8: 100% RDF + Humic acid 30 kg ha$^{-1}$ + Hydrogel 2.5 kg ha-1 | 7.38 | 0.11 | 0.44 |
| $T_9$: 100% RDF + Humic acid 30 kg ha$^{-1}$ + Hydrogel 4.5 kg ha-1 | 7.37 | 0.10 | 0.44 |
| $T_{10}$: Control | 7.40 | 0.13 | 0.41 |
| SEm (+) | 0.07 | 0.008 | 0.011 |
| CD ( P = 0.05) | NS | NS | NS |


http://dx.doi.org/10.53709/CHE.2021.v02i02.007

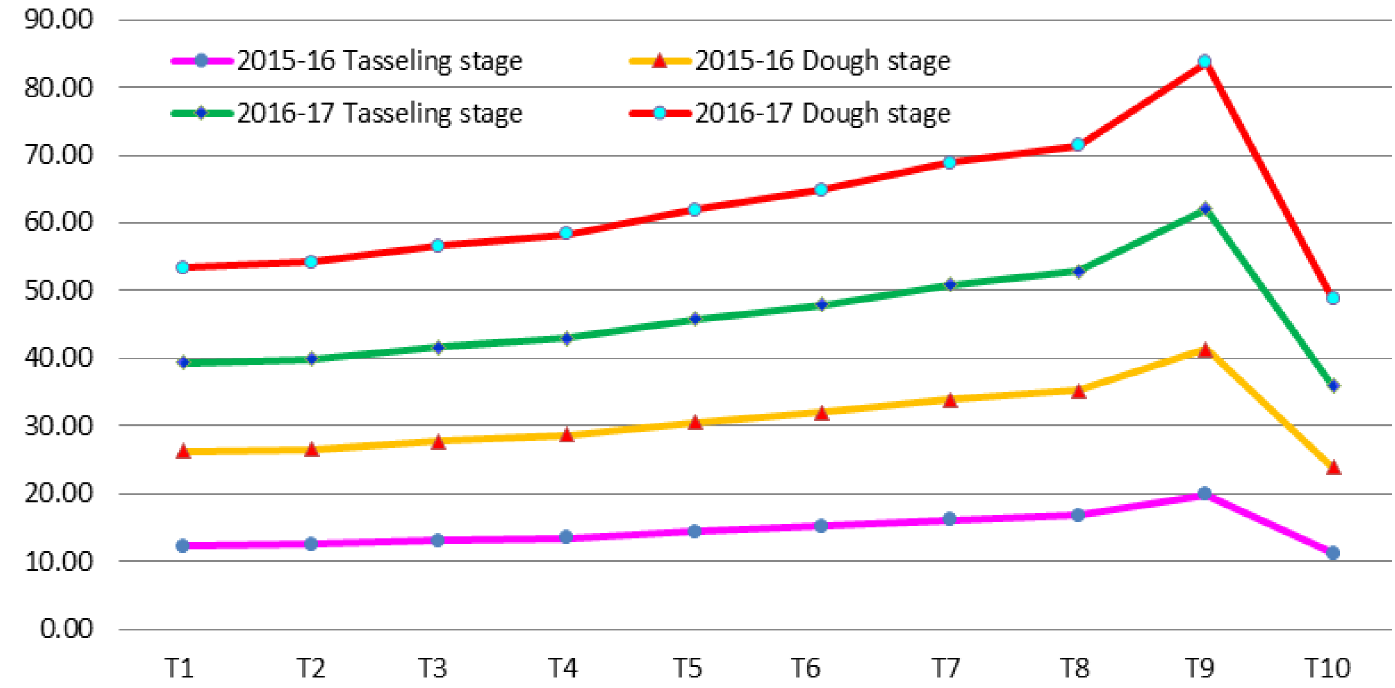


**Fig 1:** Influence of different levels of Hydrogel and Humic acid on soil moisture (%) content

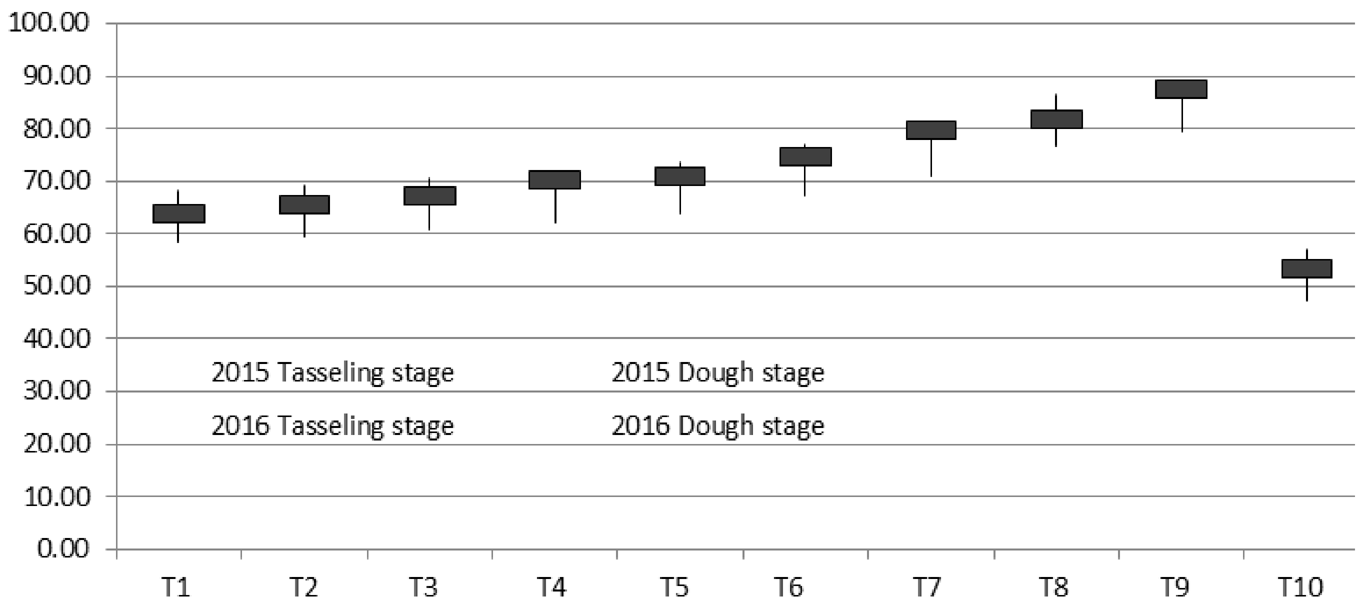


**Fig 2:** Effect of different levels of Hydrogel and Humic acid on relative water (%) content

kg $K_2O$ ha$^{-1}$ through urea, diammonium phosphate, and muriate of potash respectively. The basal dose of fertilizers (33 % N, 100 % P and 50% K) were applied at the time of sowing, and the remaining 67 % N applied in two split doses at 25 and 55 DAS, and 50% K was applied at 25 DAS by pocketing method at the base of individual plants. As per the treatment inception, required quantities of hydrogel and humic acid were applied at a depth of 8-10 cm in rows, where the test crop was sown with a spacing of 60 x 20 cm. Bulk density of the experimental soil was estimated by core sampler method and soil moisture content calculated by gravimetric method by drying the soil in oven at 105$^0$c temperature to obtain a constant weight [20]. The relative water content assessed using the ratio of tissue fresh weight to tissue turgid weight [21]. Further, physico-chemical properties (pH and EC) were determined by standard procedures given by [22]. Whereas organic carbon content was estimated by wet-oxidation method [23]. The plant-available nitrogen (N) content was estimated by alkaline permanganate method as per the procedure of [24]. Available phosphorus ($P_2O_5$) was determined by using sodium bicarbonate (0.5 $NNaHCO_3$) extractant at pH 8.5 by [25] and available potassium ($K_2O$) was extracted by neutral normal ammonium acetate


http://dx.doi.org/10.53709/CHE.2021.v02i02.007

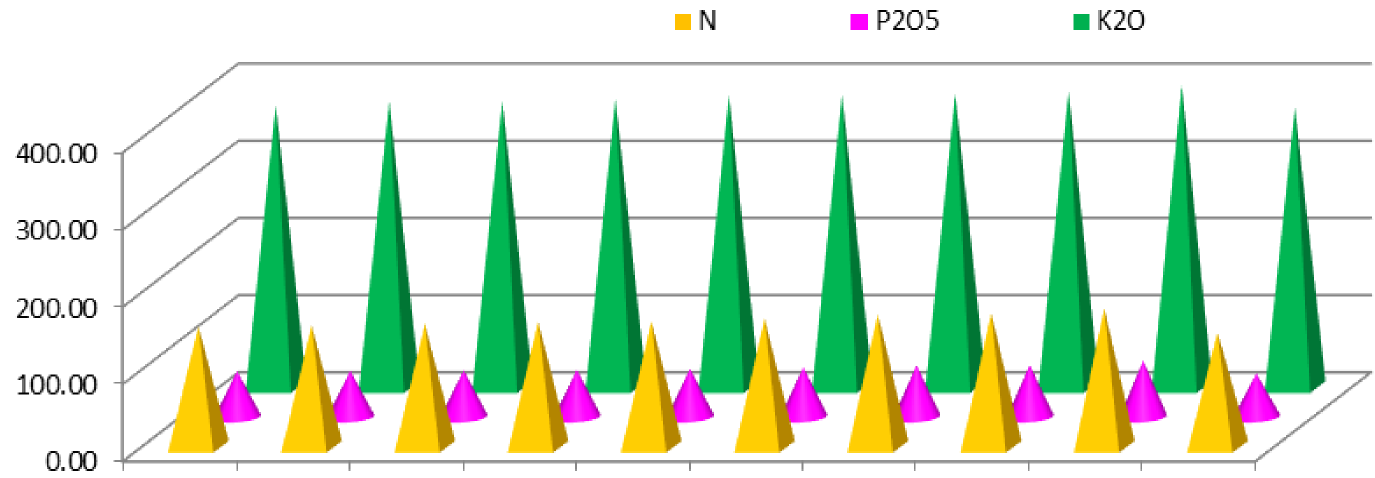


**Fig 3:** Influence of different levels of Hydrogel and Humic acid on pooled available N, P2O5 & K2O status at harvest

and measured with flame photometer [26]. The grain and stover yields were recorded at the time of harvesting from the randomly tagged five plants and expressed grain and stover yield as kilograms per hectare (Kg ha$^{-1}$).

The data was analyzed statistically in a randomized block design using OPSTAT, and significance of the treatment effect was determined using the F-test. The least significant differences were calculated at the 5% probability level to determine the significance of the difference between two treatments [27].

## RESULTS AND DISCUSSION

### Grain and Stover Yield (kg ha$^{-1}$) of Maize

The grain and stover yield of maize was influenced significantly by the application of superabsorbent polymer in combination with humic acid and 100% RDF package and is presented in Table.1. Grain and stover yield of maize varied from 4458 to 6977 and 5158 to 8363 kg ha$^{-1}$ respectively during *kharif*, 2015, and ranged 4731 to 7294 and 5346 to 8551 kg ha$^{-1}$ respectively during *kharif*, 2016. Soil application of hydrogel@4.5 kg ha$^{-1}$ + humic acid@30 kg ha$^{-1}$ along with 100% RDF produced the highest grain and stover yields (6977 & 8363 and 7294 & 8551 kg ha$^{-1}$) during *kharif*, 2015 and 2016, and was significantly higher over rest of the treatments**.** It may be attributed to improvement in the water holding capacity of the soil due to humic acid coupled with supersorbing properties of the hydrogel which absorbs the water and releases it slowly to the growing plants as per the crop requirement along with nutrients to enhance photosynthetic activity which further resultant in higher yields. Significantly lower grain and stover yields were noticed when maize was grown only with recommended dose of fertilizers (6022 & 7208 and 6319 & 7028 kg ha$^{-1}$) in both the years, and pooled yield was found as 6171 and 7122 kg ha$^{-1}$. The ultimate lowest grain and stover yields were registered on the control treatment (4458 & 5158 and 4731 & 5346 kg ha$^{-1}$ respectively), during *kharif*, 2015 & 2016; and pooled yield was noticed as 4595 & 5252 kg ha$^{-1}$ where no input was added. Further, pooled grain and stover yield varied from 4595 to 7136 and 5252 to 8457 kg ha$^{-1}$. Among the treatments, integrated soil application of hydrogel @ 4.5 kg ha$^{-1}$ + humic acid@30 kg ha$^{-1}$ with 100% RDF package has resulted in significantly highest pooled grain and stover yield (7136 and 8457 kg ha$^{-1}$), even when maize crop experienced moisture stress during crop critical stages like a knee-high stage, tasseling, cob initiation, and soft dough stage during *kharif*, 2015 and 2016. The application of super absorbent polymers increases sink capacity, which provides enough time to prepare unsaturated fatty acids from the saturated fatty acids, improve the cell membrane development, leaf area index, leaf area duration, chlorophyll, and protein content by balancing nutrient substances and higher $CO_2$ fixation through prolonged stomata opening ascribes in the enhancement of yield. Further, large quantities of water and nutrients retained near the rhizosphere zone with hydrogel applications are released in synchrony


http://dx.doi.org/10.53709/CHE.2021.v02i02.007

with plant demand, which enables water and nutrient extraction from wider and deeper soil depths by plants, and thereby, increases nitrogen, phosphorus, potassium, calcium, and magnesium uptake resulting in better growth and yield attributes. The positive effect of superabsorbent polymers in increasing the yields was reported by [28] and [29] in maize. Similarly, [30] reported an increase of 15% in corn grain yield with the humic acid application [31].

**Bulk density at harvest**

The data on bulk density (g $cm^{-3}$) of the soil (Table.2), indicated that there was no significant difference among the different combinations of humic acid and hydrogel along with recommended dose of maize fertilizers, nor their alone application at their levels. At this experiment, application of humic acid@30 kg $ha^{-1}$ along with hydrogel@4.5 kg $ha^{-1}$ and 100% RDF slightly decreased the bulk density (1.45 and 1.44 g $cm^{-3}$ during *kharif*, 2015 and 2016) as compared to that of control (1.47 and 1.46 g $cm^{-3}$ during *kharif*, 2015 and 2016) where no inputs were added. The decrease in bulk density has been attributed due to humic acid and hydrogel application, which further improved soil organic matter and root proliferation to form better aggregates [32].

**Soil moisture content and relative water content at tasseling and dough stage of maize**

As observed from Fig.1, indicates that significantly higher soil moisture content (%) observed at tasseling and dough stage of the maize crop with the application of superabsorbent polymer in combination with humic acid and 100% RDF package during *kharif*, 2015 and 2016. Among the treatments, integrated soil application of hydrogel@4.5 kg $ha^{-1}$ + humic acid@30 kg $ha^{-1}$ with 100% RDF registered in significantly higher soil moisture content as 19.95 & 21.53 and 20.66 & 21.69% at tasseling and dough stages during *kharif*, 2015 and 2016 respectively as compared to that of 100% RDF (12.28 & 13.96 and 13.09 & 14.12% at tasseling and dough stage during *kharif*, 2015 and 2016 respectively) where no inputs were added. Conjunctive application of humic acid@30 and hydrogel@4.5 kg $ha^{-1}$ increased the soil moisture content of the experimental site due to its adsorptive nature to improve soil porosity (Li *et al.,* 2019). Further, improved soil parameters at plough layer had a direct influence to improve soil moisture content (Bhanavase *et al.,* 2011).

The relative water content (%) was significantly affected by the judicious use of super absorbent polymers + humic acid along with recommended fertilizer package (Fig.2) at tasseling and dough stage of maize crop during *kharif*, 2015 and 2016. Among different treatments, integrated application of hydrogel@4.5 kg $ha^{-1}$ + humic acid@30 kg $ha^{-1}$ with 100% RDF was found to be the best nutrient management practice which resulted in significantly higher relative water content as 89.30 & 79.25 and 89.03 & 85.93% at tasseling and dough stages during *kharif*, 2015 and 2016 respectively in comparison to alone application of 100% RDF (65.38 & 58.37 and 68.15 & 62.01% respectively. Hydrogel provides a reservoir of soil water in the root zone by preventing leaching and deep percolation losses. The higher retention pores, and low saturated hydraulic conductivity under hydrogel amended treatments reduced drainage pores aided a favorable soil-water-plant continuum to improve relative water content in maize crop [33].

**Soil physico-chemical parameters at harvest**

The pooled physico-chemical parameters (pH, EC and OC) of the soil (Table.3) indicated that there was no significant difference among the treatments, which comprised various levels of humic acid and hydrogel along with recommended dose of maize fertilizers, nor their alone application. Integration of humic acid@30 kg $ha^{-1}$ and hydrogel@4.5 kg $ha^{-1}$ with 100% maize RDF package slightly decreased the soil pH and EC as 7.41 & 0.10 $dSm^{-1}$, compare to the alone application of 100% RDF through chemical fertilizers (7.41 and 0.14 $dSm^{-1}$). The incorporation of humic acid substances with hydrogel resulted in stronger buffering behavior which stabilizes the rhizosphere environment to promote plant growth [34]. With the placement of humic acid@30 kg $ha^{-1}$ + hydrogel@4.5 kg $ha^{-1}$ with 100% RDF improved soil organic carbon content little extent as 0.44% compared to the 100% RDF application (0.42%), and control treatment (0.41%), where no inputs were applied for crop growth. As shown in Table 4, treatments with humic acid and hydrogel addition increased little amount of organic carbon content compared to the treatments which didn't receive the humic acid and hydrogel substrates. Humic acid is


http://dx.doi.org/10.53709/CHE.2021.v02i02.007

a macromolecular organic substance rich in organic carbon [35] which has an ample amount of oxygen-containing functional groups, such as carboxyl and phenolic hydroxyl groups on the surface of humic acid substance [36].

### Available macro-nutrient (N, $P_2O_5$ & $K_2O$) status at harvest

The available macro-nutrients *viz.,* N, $P_2O_5$ & $K_2O$ (kg $ha^{-1}$) status influenced significantly by the application of superabsorbent polymer in combination with humic acid and 100% RDF package and presented in Fig.3. The pooled available macro-nutrients ranged from 147.88 to 179.30, 56.33 to 72.88 and 362.11 to 391.01 kg of N, $P_2O_5$ & $K_2O$ $ha^{-1}$ respectively. Humic acid is a bio-stimulant substance that can improve biochemical and soil properties with increased uptake of macro and micronutrients (El-Howeity *et al.,* 2019), Soil application of hydrogel@4.5 kg $ha^{-1}$ + humic acid@30 kg $ha^{-1}$ along with 100% RDF registered highest available nutrients as 179.30, 72.88 and 391.01 kg of N, $P_2O_5$ & $K_2O$ $ha^{-1}$ respectively, and was significantly higher over rest of the treatments. It may be attributed to enhancement of cell permeability due to the stimulative effect of humic acid in conjunction with hydrogel and mineral constituents turn to more rapid entry of nutrients into root cell, and resulted in higher uptake of plant nutrients and also promoted higher nutrient availability at rhizosphere [37]. The ultimate low available nutrients were registered in control treatment (147.88, 56.33 and 361.11 kg N, $P_2O_5$ & $K_2O$ $ha^{-1}$ respectively), where no input was added. The least nutrient status in the control treatment was probably due to lack of moisture coupled with nutrient deficiencies reducing rhizosphere activities to obtain nutrients [34].

## CONCLUSION

This study suggests that the use of hydrogel@4.5 kg $ha^{-1}$ + humic acid@30 kg $ha^{-1}$ along with 100% RDF improves maize production levels, soil physical and chemical parameters in Alfisols. At limited irrigation sources, application of hydrogel could be utilized adequately to mitigate moisture stress during crop critical growth stages under rainfed conditions, and humic substances ameliorate dryland soils to improve crop uptake and available nutrient status.

## REFERENCES

1. Abd El-Razek E, Haggag LF, MMM A-E-M, El-Hady Combined ES (2018) Effects of soil applications of humic acid and foliar spray of amino acids on yield and fruit quality of 'Florida Prince' peach trees under calcareous soil conditions. Bioscience Research 15:3270–3282

2. Abdallah, Ahmad M.. "The effect of hydrogel particle size on water retention properties and availability under water stress." *International Soil and Water Conservation Research* 7 (2019): 275-285.

3. Abdulameer, OQ, Ahmed, A. (2019). Role of Humic acid in improving growth characters of corn under water stress. Iraqi Journal of Agricultural Sciences, 50(1). https://doi.org/10.36103/ijas.v50i1.308

4. Abourayya, M.S., Kaseem, N.E., Mahmoud, T.S.M. *et al.* Impact of soil application with humic acid and foliar spray of milagro bio-stimulant on vegetative growth and mineral nutrient uptake of Nonpareil almond young trees under Nubaria conditions. *Bull Natl Res Cent* 44, 38 (2020). https://doi.org/10.1186/s42269-020-00296-x

5. Agricultural Market Intelligence, Department of AgriculturalEconomics, College of Agriculture, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendranagar, Hyderabad, Telangana, India

6. Azeem K, Farah Naz Arshad JalalFernando S. GalindoMarcelo C. M. Teixeira FilhoFarhan Khalil. Humic acid and nitrogen dose application in corn crop under alkaline soil conditions. Revista Brasileira de Engenharia Agrícola e Ambiental [online]. 2021, v. 25, n. 10 [Accessed 2 January 2022] , pp. 657-663. Available from: <https://doi.org/10.1590/1807-1929/agriambi.v25n10p657-663>.

7. Baldotto, M. A.; Melo, R. O.; Baldotto, L. B. Field corn yield in response to humic acids application in the absence or presence of liming and mineral fertilization. Semina: CienciasAgrarias, v.40, p.3299-3304,

2019. https://doi.org/10.5433/1679-0359.2019v40n6Supl2p3299

8. Bijanzadeh, E.; Naderi, R.; Egan, T.P. Exogenous application of humic acid and salicylic acid to alleviate seedling drought stress in two corn (*Zea mays* L.) hybrids. Journal of Plant Nutrition, v.42, p.1483-1945, 2019. https://doi.org/10.1080/01904167.201 9.1617312

9. Black C.A. 1965. "Methods of Soil Analysis: Part I Physical and mineralogical properties". American Society of Agronomy, Madison, Wisconsin, USA.

10. Cechmánková, J.; Skála, J.; Sedlaˇrík, V.; Duˇrpeková, S.; Drbohlav, J.; Šalaková, A.; Vácha, R. The Synergic Effect of Whey-Based Hydrogel Amendment on Soil Water Holding Capacity and Availability of Nutrients for More Efficient Valorization of Dairy By-Products. Sustainability 2021, 13, 10701. https://doi.org/10.3390/su131910701