

Influence of Super Absorbent Polymer and Humic Acid on Maize Yield and Nutrient Uptake on Rainfed Alfisols

ABSTRACT

The advances and development in agriculture depend not only on mechanization and new hybrid seeds but also on the improvement of soil physical and chemical properties which in turn help to increase crop productivity in dry land soils. A field study was carried out to study the influence 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 recommended 100% fertilizers on yield, uptake, and photosynthetic pigments of maize grown on rainfed alfisols at Regional Agricultural Research Station, Palem, Telangana. The experiment was laid out in randomized block design with three replications, consisting of nine treatments. Further, results showed that 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. Irrespective level of hydrogel and humic acid combinations with 100% RDF increased the macronutrient uptake by grain and stover, which further build up the total uptake. A similar pattern was also observed in corresponding to grain and stover yield. The chlorophyll "a", "b" and total chlorophyll content (1.81, 1.69, 1.54; 0.69, 0.62, 0.55 and 2.65, 2.46 and 2.24 mg g⁻¹ in fresh plant weight at 30, 60 and 90 DAS) significantly influenced by application of hydrogel@4.5 kg ha⁻¹ + humic acid@30 kg ha⁻¹. In conclusion, the present investigation indicates the positive interaction between humic acid and super absorbent polymer which improved nutrient uptake and maize yield.

Keywords: Super absorbent polymer, Humic acid, Hydrogel, fertilizer, Maize, and Chlorophyll content

1. INTRODUCTION

In many regions of the world, including India, drought stress is one of the most important factors that decrease agricultural crop production (Sah *et al.*, 2020). Maize is the third leading 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 the erratic distribution of rainfall, and dry spell finally leads to reduced crop yields. In view of global climate change, drought stress aggravates soil moisture availability especially during grain development, which is responsible for 20–30 % yield losses mainly due to undersized kernels (Gao *et al.*, 2017). 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 by improving water relations in sandy soils (Dai *et al.*, 2017). 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. According to this basis, one of the ways to improve the soil moisture in Alfisols is applying super absorbent polymer along with organic substances that supply water and nutrients for crop roots (Pawlowski *et al.*, 2009).

Hydrogels are superabsorbent polymers (SAPs), which hold 332-465 times water of their weight through osmosis properties and are characterized as hydrophilic, three dimensional cross linked functional polymers. These can be classified into two main groups according to their physicochemical properties. The first group of polymers was reversible hydrogels, in which polymer chains are linked by electrostatic forces, hydrogen bonds and hydrophobic interactions and are unstable, easily converted into

a polymer mixture by heating. The second group is chemically stable hydrogels, in which the polymer chains are linked by stable covalent bonds with starch and vinyl monomers. In agriculture, second group of hydrogels were preferred commonly as potassium polyacrylate or sodium polyacrylate and these polymers absorb the conserved rain and other moisture, releasing it gradually at later stages to meet the water requirement of the crop in drought stress conditions, and also prolong the irrigation interval in light soils (Dehkordi, 2016). The hydrogels reduce nutrient losses by preventing leaching, especially nitrogen and potassium. It, thus, promotes synchrony in nutrient release and uptake of nutrients as needed by crop plants (Mendonça *et al.*, 2013).

Several research workers highlighted the positive benefits (Rehman *et al.*, 2011; Singh, 2012; Langaroodi *et al.*, 2013) in terms of moisture conservation, as well as yield improvement in many crops. During the last couple of decades, because of negative environmental impact of chemical fertilizers, application of organic sources in various parts of the world has increased. The effect of organic matter on the soil properties such as physical, chemical, and biological ones has been well known for a long time. The soil organic matter mainly consists of humic and fulvic acids which are called humin materials, which were mainly produced from nitrogenous compounds containing decomposed amino acids and aromatic complexes. Those organic complexes affect the soil properties and physiological properties of plants due to their carboxyl (COOH⁻) and phenolic (OH⁻) groups. Humic acid is an organically charged bio-stimulant that significantly affects plant growth and development to increase crop yield. It has been extensively investigated (Liu *et al.*, 2019) that humic acid stimulates microbial activities in the rhizosphere due to the biochemical decomposition of animal and plant residues (El-Howeity *et al.*, 2019), improves photosynthetic efficiency and soil-water properties (Shah *et al.*, 2018b). Many authors have highlighted the production advantages of humic acid application on various crops (Morozesk *et al.*, 2017; Olaetxea *et al.*, 2018), further it also helps in moisture retention and mitigation of salinity (Yoon- Ha Kim *et al.*, 2012). The studies made to understand the combined application of superabsorbent polymers with humic acid substances were lacking. Apart from this, the physiological basis for improvement of yield when applied SAP materials with humic acid needed to be understood in detail.

2. 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 uptake 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 P₂O₅ (61.38 kg ha⁻¹) and medium in K₂O (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: T₁: 100% RDF, T₂:100% RDF + Humic acid 15 kg ha⁻¹, T₃:100% RDF + Humic acid 30 kg ha⁻¹, T₄: 100% RDF + Hydrogel 2.5 kg ha⁻¹, T₅:100% RDF + Hydrogel 4.5 kg ha⁻¹, T₆:100% RDF + Humic acid 15 + Hydrogel 2.5 kg ha⁻¹, T₇:100% RDF + Humic acid 15 + Hydrogel 4.5 kg ha⁻¹, T₈:100% RDF + Humic acid 30 + Hydrogel 2.5 kg ha⁻¹, T₉:100% 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 P₂O₅ and 50 kg K₂O 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. The plant samples were collected for the analysis of photosynthetic pigments by following Lichtenthaler and Wellburn (1983) method and nutrient uptake studies described by

Piper (1966). 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}).

Further, 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 (Gomez and Gomez, 1984).

3. RESULTS AND DISCUSSION

3.1 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 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 Gunese *et al.*, (2016) and Kumari *et al.*, (2017) in maize. Similarly, Baldotto *et al.*, (2019) reported an increase of 15% in corn grain yield with the humic acid application (Oktem *et al.*, 2018).

3.2 Macro-Nutrient Uptake (kg ha^{-1}) of Maize in Grain and Stover

The pooled macronutrient (NPK) uptake in grain and stover was significantly affected by the judicious use of super absorbent polymers + humic acid along with recommended fertilizer package (Fig1, 2 and 3) at harvest. Among different treatments, integration 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 N, P, K uptake in grain and stover (88.86, 17.90, 88.84 and 61.47, 21.42, 93.14 kg ha^{-1}), and total uptake (150.33, 39.32 and 131.99 kg ha^{-1}) respectively in comparison to alone application of 100% RDF (67.97,

11.81, 26.45 and 37.55, 13.84, 67.40 kg ha⁻¹), with total uptake of 103.11, 25.83 and 95.29 kg ha⁻¹ respectively. The higher NPK uptake registered with the application of 100% RDF along with hydrogel@4.5 kg ha⁻¹ + humic acid@30 kg ha⁻¹ than alone 100% RDF package may be attributed to better crop growth due to higher removal of nutrients by availing moisture for nitrification process reported by Mandal *et al.* (2015) in maize crop. 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 soil reduce the drainage pores, thereby maintain high moisture content to activate favorable chemical reactions in the soil (Shahid *et al.*, 2016), which aided a favorable soil-water-plant continuum for nutrient uptake.

3.3 Chlorophyll ‘a’, ‘b’ and total chlorophyll content (mg g⁻¹) of Maize

The pooled data on chlorophyll “a”, “b” and total chlorophyll content of maize at different growth stages are presented in Fig 2. Application of 100% RDF along with hydrogel@4.5 kg ha⁻¹ + humic acid@30 kg ha⁻¹ resulted in significantly higher chlorophyll “a” (1.81, 1.69 and 1.54 mg g⁻¹ fresh weight at 30, 60 and 90 DAS respectively), chlorophyll “b” (0.69, 0.62 and 0.55 mg g⁻¹ fresh weight at 30, 60 and 90 DAS respectively) and total chlorophyll content (2.65, 2.46 and 2.24 mg g⁻¹ fresh weight at 30, 60 and 90 DAS respectively). Whereas, significantly lower chlorophyll “a” (1.54, 1.37 and 1.22 mg g⁻¹ fresh weight at 30, 60 and 90 DAS respectively), chlorophyll “b” (0.45, 0.42 and 0.38 mg g⁻¹ fresh weight at 30, 60 and 90 DAS respectively) and total chlorophyll content (2.13, 1.97 and 1.75 mg g⁻¹ fresh weight at 30, 60 and 90 DAS respectively) was noticed in maize with the alone application of recommended fertilizer package. Application of 100% RDF coupled with hydrogel@4.5 kg ha⁻¹ + humic acid@30 kg ha⁻¹ has recorded significantly higher chlorophyll “a”, “b” and total chlorophyll content compared to the maize grown with the alone application of recommended fertilizer dosage and it confirms the positive relationship with grain yield of maize. According to Akhter *et al.*, (2004), addition of 0.1, 0.2 and 0.3% hydrogel increased the moisture retention at field capacity with a linear correlation of $r = 0.988$, thus the amount of plant-available water was significant in both sandy loam and loam soils. The application of hydrogel can avoid moisture deficit and improve crop yield (Mohammadkhani and Heidari, 2007).

4. CONCLUSION

Application of hydrogel@4.5 kg ha⁻¹ + humic acid@30 kg ha⁻¹ along with 100% recommended fertilizer package on Alfisols resulted in the highest pooled grain and stover yield of maize, *i.e.*, 7136 and 8457 kg ha⁻¹ respectively. Conjoint application of super absorbent polymers along with humic acid substances had a positive influence on yield and survivability of maize plants under moisture deficit conditions on rainfed Alfisols, especially at critical growth stages of maize.

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 |

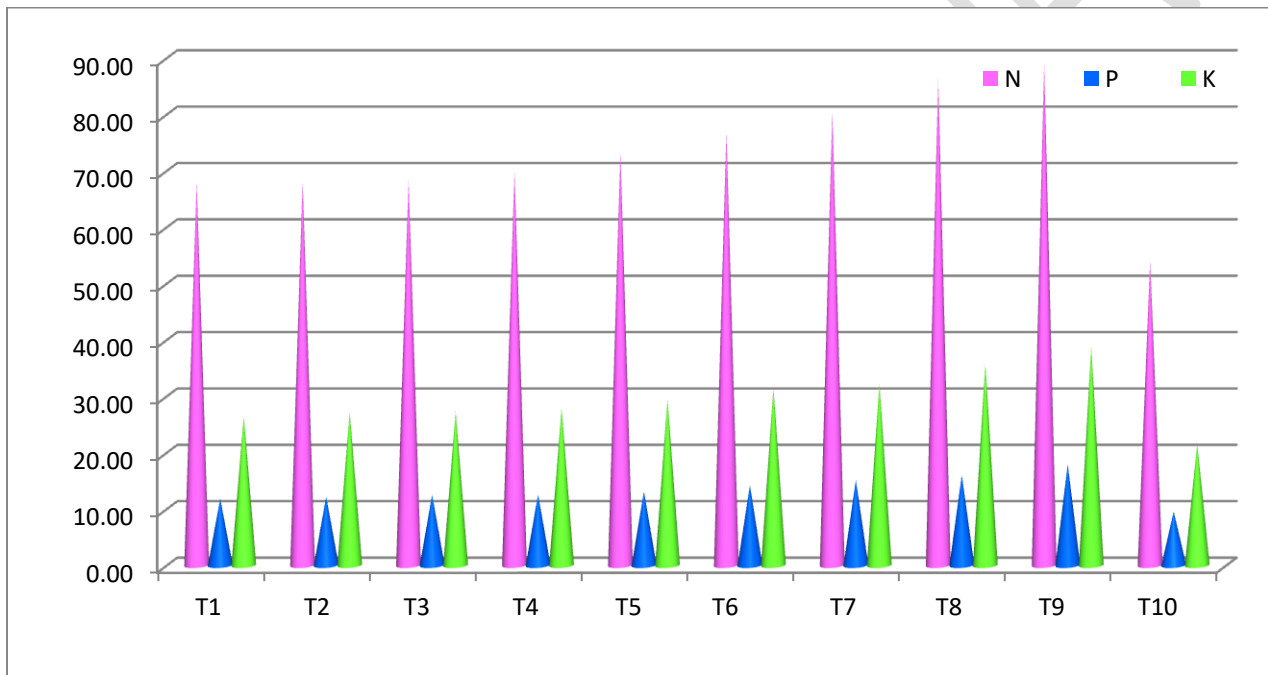


Fig 1. Effect of different levels of Hydrogel and Humic acid on pooled grain NPK uptake (kg ha⁻¹) of maize

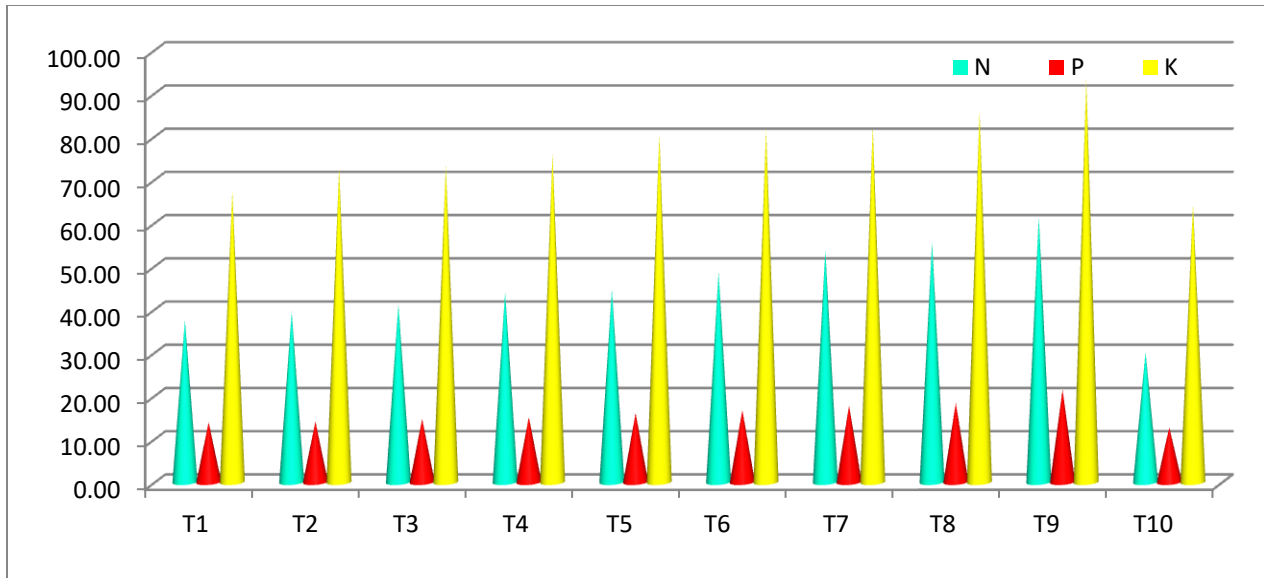


Fig 2. Influence of different levels of Hydrogel and Humic acid on pooled stover NPK uptake (kg ha⁻¹) of maize

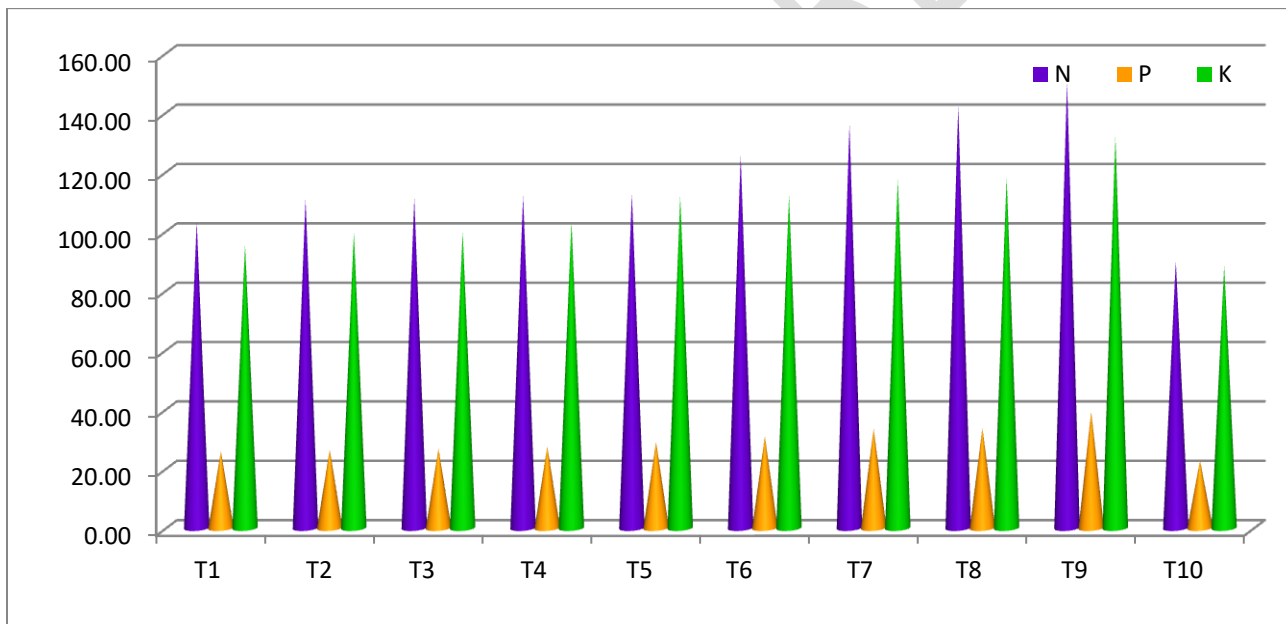


Fig 3. Influence of different levels of Hydrogel and Humic acid on pooled total NPK uptake (kg ha⁻¹) of maize

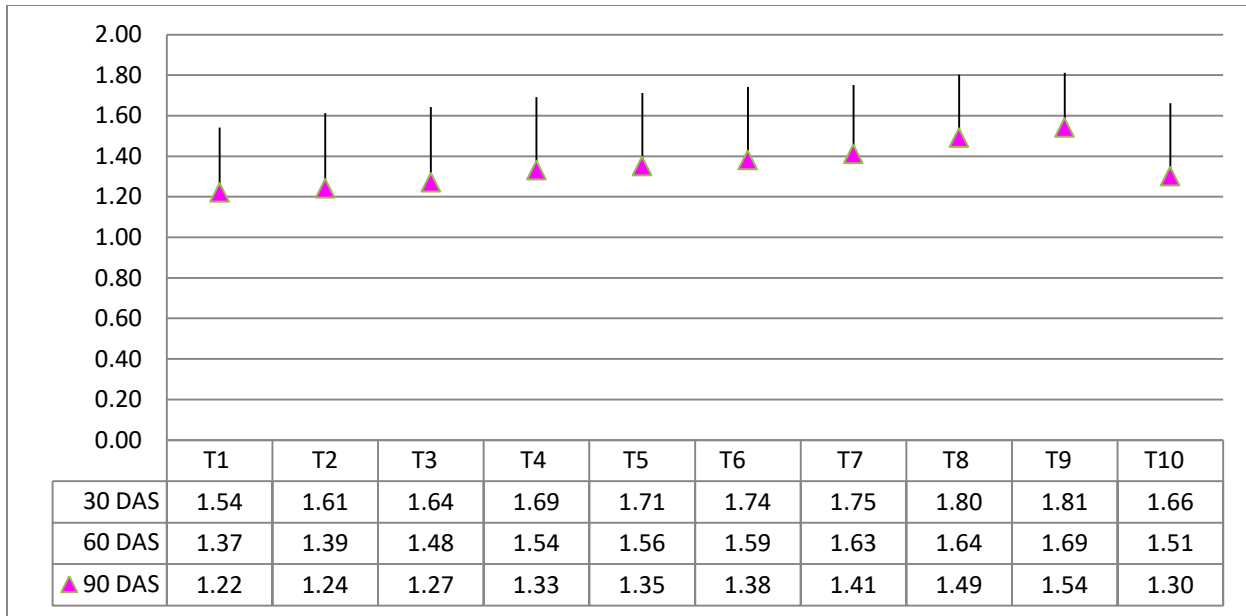


Fig 4. Effect of different levels of Hydrogel and Humic acid on pooled chlorophyll “a” (mg g^{-1}) of maize

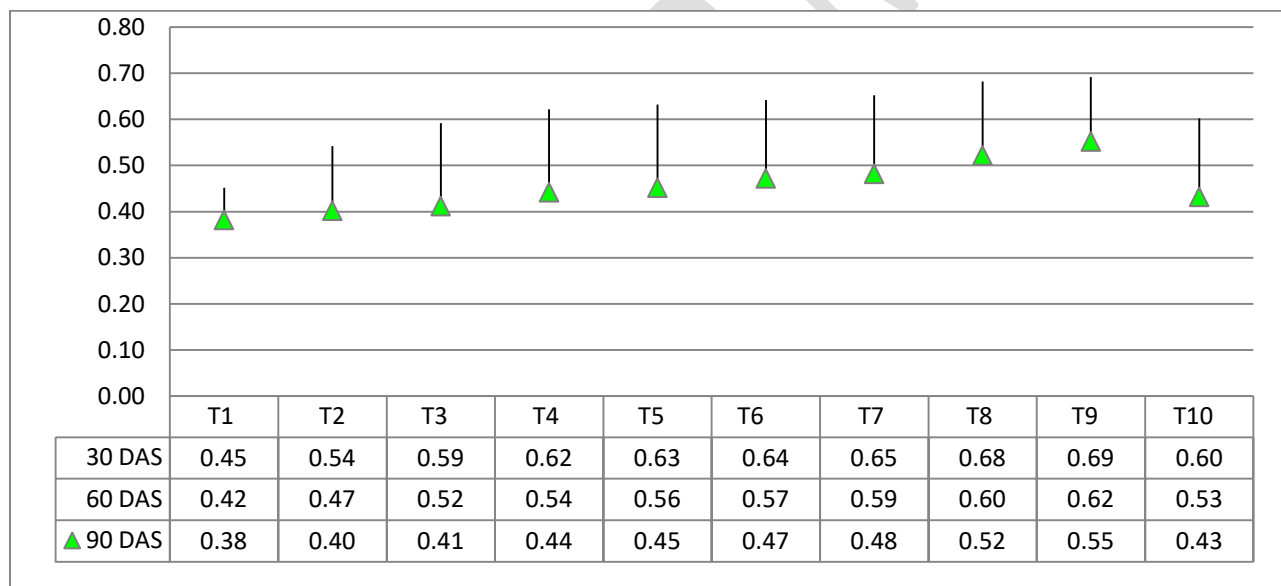


Fig 5. Effect of different levels of Hydrogel and Humic acid on pooled chlorophyll “b” (mg g^{-1}) of maize

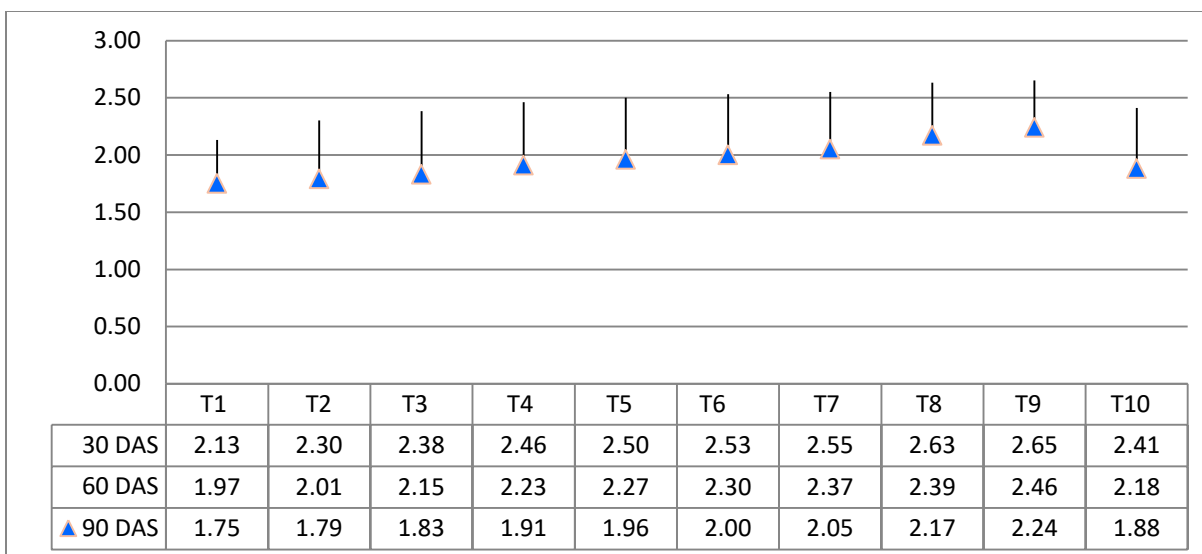


Fig 6. Effect of different levels of Hydrogel and Humic acid on pooled total chlorophyll (mg g^{-1}) of maize

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