Performance of Super Absorbent Polymer and Humic Acid on Maize Yield and Uptake under Rainfed Alfisols

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 recommended 100% fertilizers on yield, uptake, and photosynthetic pigments 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. Irrespective level of hydrogel and humic acid combinations with 100% RDF increased the macronutrient uptake by grain, stover and total uptake and showed a similar pattern as observed in corresponding to grain and stover yield. The higher 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} fresh weight at 30, 60 and 90 DAS) were significantly influenced with the soil application of hydrogel@4.5 kg ha^{-1}+ humic acid@30 kg ha^{-1}. The present investigation indicates the positive interaction of humic acid with super absorbent polymer to improve maize yield and uptake.

Comment [PM1]: Make it separated chlorophyll a, b and total chlorophyll

***Keywords:** Super absorbent polymer, Humic acid, Hydrogel, Recommended dose of 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, and it seems to be moderately forbearing the moisture stress in Alfisols. 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, which leads terminal dry spell finally leading to reduced yields. In view of global climate change, drought stress aggravates soil moisture availability especially during grain development, and is responsible for 20–30 % yield losses mainly due to undersized kernels (Gao *et al.,* 2017). According to this basis, one of the ways to improve the soil moisture in Alfisoils is applying super absorbent polymer along with organic substances that supply water and nutrients for crop roots (Pawlowski *et al.,* 2009).

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Hydrogels are superabsorbent polymers (SAPs) which on an average, hold 332-465 times water of its weight and release it slowly in drought stress conditions in light soils (Dehkordi, 2016) to regulate soil water availability to crops and to favor the efficiency of nutrient absorption to improve the crop yields (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. On the other hand, 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.

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2. MATERIAL AND METHODS

A field experiment was conducted at Regional Agricultural Research Station, Professor Jayashankar Telangana State Agricultural University, Palem, Telangana state, India during *kharif,* 2015 and 2016 under rainfed conditions to find out the performance of conjoint application of hydrogel and humic acid on maize yield and uptake in Alfisols. The experimental soil 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 randomized block design with ten treatments replicated thrice, consists combination of two factors *i.e.,* hydrogel and humic acid with control treatment where no input was applied. The maize hybrid DHM 117 used as test crop by imposing treatment composition as 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 kg K_2O ha^{-1} through urea, diammonium phosphate, and muriate of potash. 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 Wellbum (1983) method and nutrient uptake studies described by Piper (1966). The grain and stover yield was 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}).

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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 influenced significantly by the application of superabsorbent polymers 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 recorded highest grain and stover yield (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 found as 6171 and 7122 kg ha^{-1}, compared to the significantly highest yield registered treatment (100% RDF + Humic acid 30 + Hydrogel 4.5 kg ha^{-1}). The ultimate lowest grain and stover yields were registered in 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 higher 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 positive effect of superabsorbent polymers in increasing the yields was reported by Gunes *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 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 of test crop (Fig 1) 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 of maize grain and stover 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. With the available soil moisture content, the nutrients may also be released from the saturated zone resulted in higher uptake of nutrients (Shahid *et al*., 2016).

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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 was influenced at different growth stages are presented in Fig 2. Soil application of 100% RDF along with hydrogel@4.5 kg ha^{-1} + humic acid@30 kg ha^{-1} recorded 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 linearly (r= 0.988), thus the amount of plant-available water significant in both sandy loam and loam soils, which helped the crop further to avoid moisture deficit and to improve crop yield (Mohammadkhani and Heidari, 2007), compared to without hydrogel application **(required more discussion)**

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4. CONCLUSION

The results of this experiment indicated that soil application of hydrogel@4.5 kg ha^{-1} + humic acid@30 kg ha^{-1} along with 100% recommended fertilizer package resulted in the highest pooled grain and stover yield of 7136 and 8457 kg ha^{-1} and was found better than other treatments. Conjoint application of super absorbent polymers along with humic acid substances had a positive influence on yield by increasing survivability of maize plants under moisture deficit conditions, especially at critical growth stages of maize grown alfisols under rainfed conditions.

favored the physiological activities and

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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

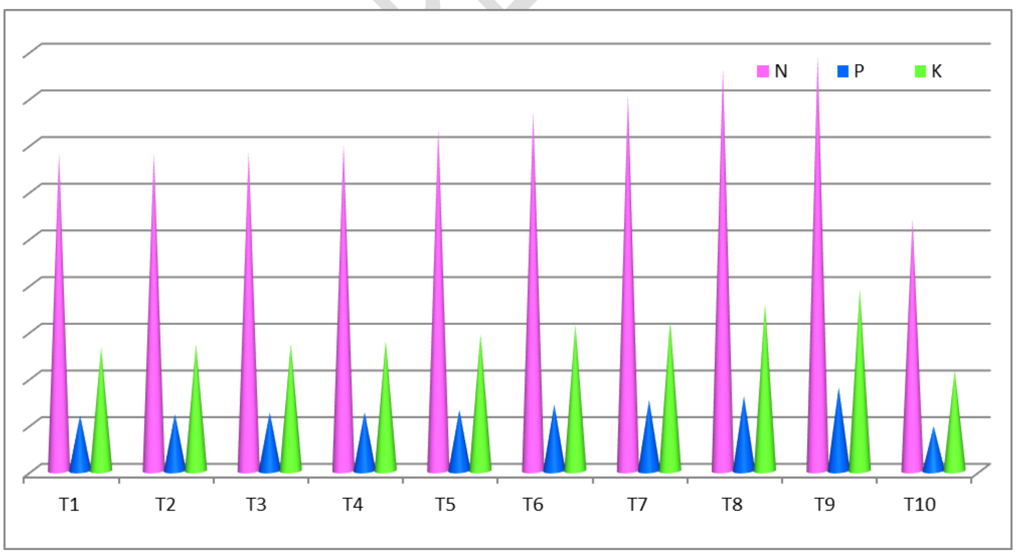


Fig 1. Effect of different levels of Hydrogel and Humic acid on pooled grain NPK uptake (kg ha^{-1}) of maize

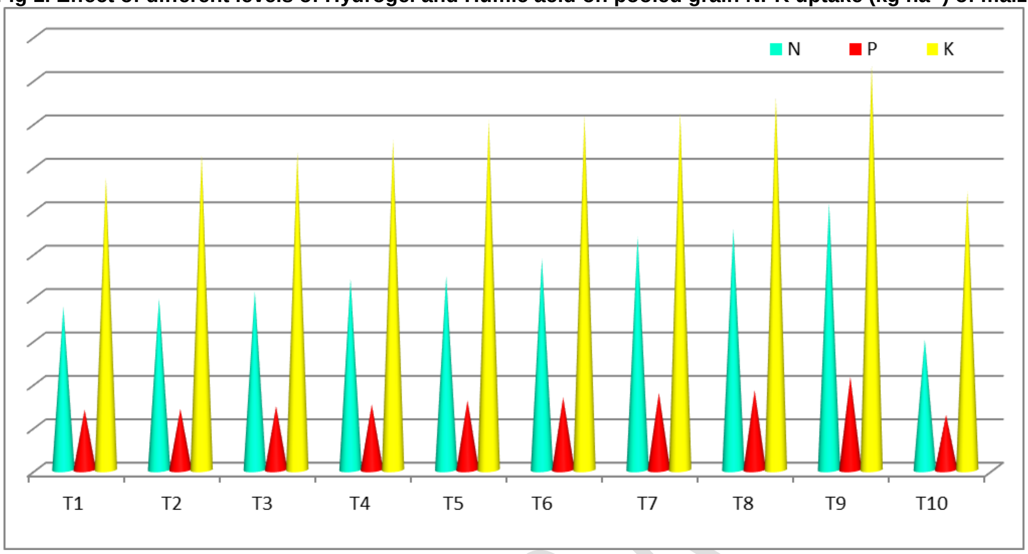


Fig 2. Influence of different levels of Hydrogel and Humic acid on pooled stover NPK uptake (kg ha^{-1}) of maize

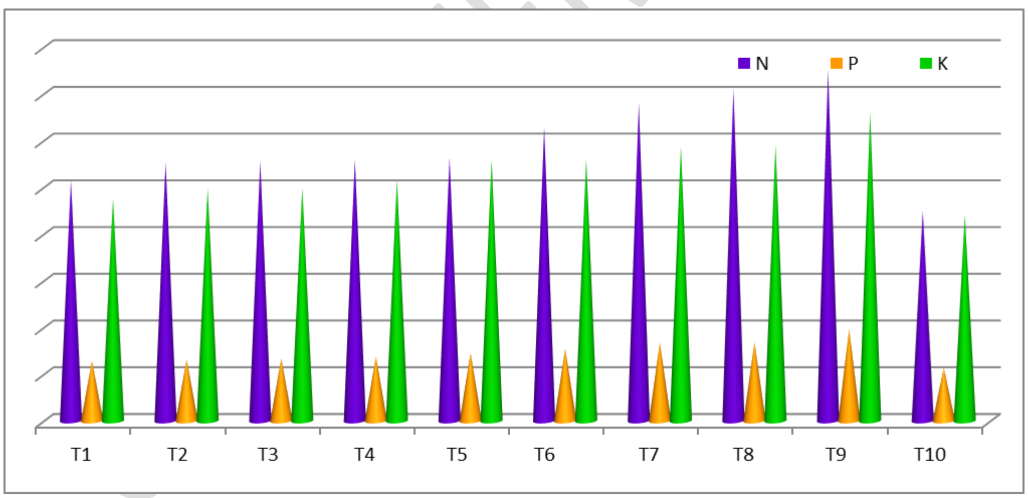
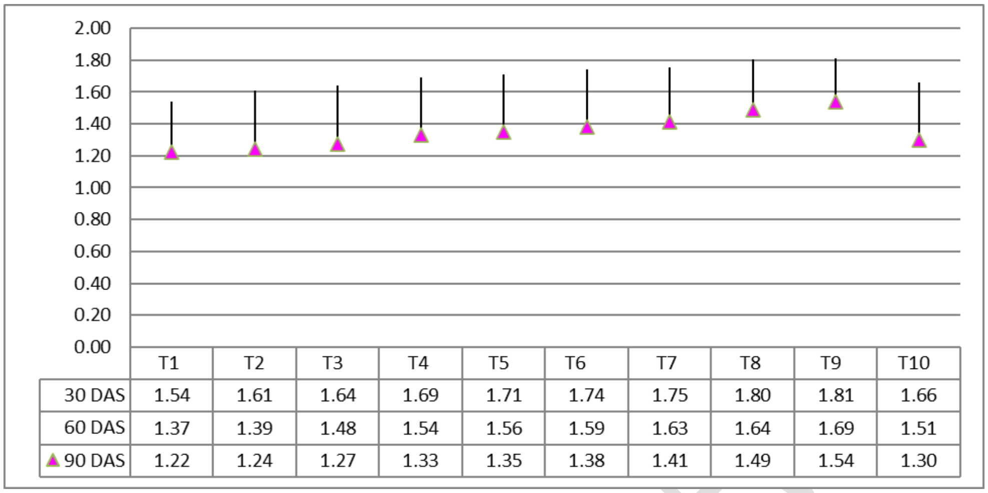
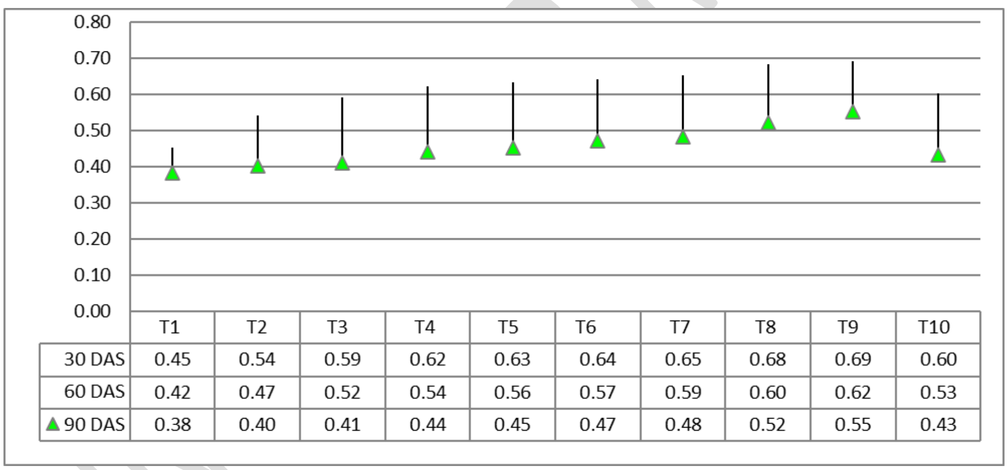


Fig 3. Influence of different levels of Hydrogel and Humic acid on pooled total NPK uptake (kg ha^{-1}) of maize



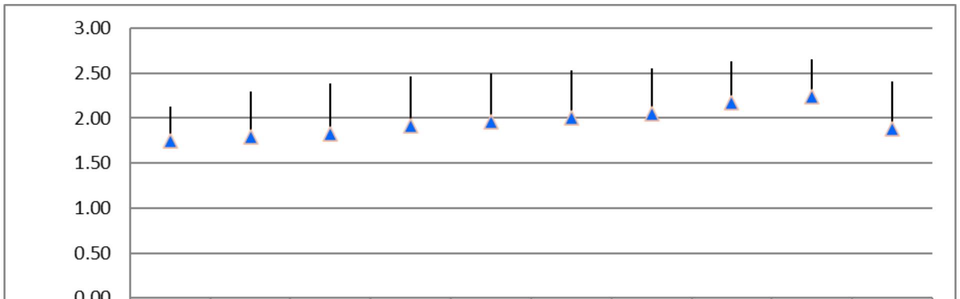
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
30 DAS	1.54	1.61	1.64	1.69	1.71	1.74	1.75	1.80	1.81	1.66
60 DAS	1.37	1.39	1.48	1.54	1.56	1.59	1.63	1.64	1.69	1.51
90 DAS	1.22	1.24	1.27	1.33	1.35	1.38	1.41	1.49	1.54	1.30

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



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
30 DAS	0.45	0.54	0.59	0.62	0.63	0.64	0.65	0.68	0.69	0.60
60 DAS	0.42	0.47	0.52	0.54	0.56	0.57	0.59	0.60	0.62	0.53
90 DAS	0.38	0.40	0.41	0.44	0.45	0.47	0.48	0.52	0.55	0.43

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



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
30 DAS	2.13	2.30	2.38	2.46	2.50	2.53	2.55	2.63	2.65	2.41
60 DAS	1.97	2.01	2.15	2.23	2.27	2.30	2.37	2.39	2.46	2.18
90 DAS	1.75	1.79	1.83	1.91	1.96	2.00	2.05	2.17	2.24	1.88

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

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Comment [PM12]: Check references in introduction

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