

Original Research Article

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Yield and Physiological Parameters of Maize as Influenced by the Application of Super Absorbent Polymer and Mulching Under Rainfed Conditions

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ABSTRACT

Water deficit is one of the principal abiotic stresses which adversely affect the crop growth and yield. Drought induces the metabolic functions such as reduced synthesis of photosynthetic pigments, the decline in the chlorophyll stability and alternations in physiological parameters. A field study was carried out to study the effect of the application of superabsorbent polymer alone and also with pongamia leaf mulching on yield and physiological parameters of maize under rainfed conditions at Zonal Agricultural and Horticultural Research Station, Babbur Farm, Hiriyyur, Karnataka during *Kharif* 2017. The superabsorbent polymer as Pusa hydrogel or commercial hydrogel at 2.5 and 5.0 kg ha⁻¹ and pongamia leaf mulch at 4.0 t ha⁻¹ alone and their combinations were the treatments. The results of this study showed that Chlorophyll 'a', chlorophyll 'b', total chlorophyll content and chlorophyll stability index of maize were higher with soil application of commercial hydrogel @ 5.0 kg ha⁻¹+ mulching with pongamia green leaf @ 4.0 t ha⁻¹ at 30, 60 and 90 DAS. Similarly higher maize kernel yield was also recorded with the application of commercial hydrogel @ 5.0 kg ha⁻¹+ mulching with pongamia green leaf @ 4.0 t ha⁻¹. There exists a positive correlation between maize kernel yield with chlorophyll 'a', chlorophyll 'b', total chlorophyll content and chlorophyll stability index.

Keywords

Chlorophyll, Super absorbent polymer, Hydrogel, Chlorophyll stability index

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Introduction

Maize (*Zea mays* L.) is a cereal grain called “queen of cereals” is the third most important cereal crop in India after rice and wheat. In India, is grown in an area of 8.69 m ha and production of 21.81 mt with the average productivity of 2509 kg ha⁻¹. Karnataka is one of the major producers of maize with an area of 1.18 m ha and a production of 3.27 mt with the productivity of 2773 kg ha⁻¹ (Anon., 2016).

Majority of the maize in Karnataka is grown under rainfed conditions and the occurrence of drought limits the productivity during different growth stages. Drought stress during post-anthesis stages is responsible for kernel weight reduction (Oveysi *et al.*, 2010). It is reported that drought stress during kernel development is responsible for 20–30 % yield losses which are mainly due to undersized kernels (Heinigre, 2000). Another report mentioned that drought prevalence during

kernel development can cause 2.5–5.8 % yield losses on a daily basis (Lauer, 2003).

Several drought management options were developed from watershed level to individual crop. Among the several drought management options, use of superabsorbent polymers or hydrogel alone or coupled with locally available mulching materials found to be usable by individual farmers, eco-friendly and cost-effective.

The superabsorbent polymer or hydrogel is water retaining, cross-linked hydrophilic, biodegradable amorphous polymer which can absorb and keep water at least 400 times of its original weight and make at least 95 per cent of stored water available for crop absorption (Johnson and Veltkamp, 1985). These synthetic polymers found in the form of crystals and available under several trade names *viz.*, super absorbent, pusa hydrogel, commercial hydrogel are collectively called hydrogel. Pusa hydrogel is a novel semi-synthetic superabsorbent polymer developed by the Indian Agricultural Research Institute. Hydrogels are safe and non-toxic and it will finally decompose to carbon dioxide, water and ammonia without any residue (Mikkelsen, 1994).

In arid and semiarid regions, use of superabsorbent polymers (SAP) may effectively increase water and fertilizer use efficiency in crops. These polymers after incorporated with soil, retain large quantities of water and nutrients, which are released as required by the plant. Thus, plant growth could be improved with limited water supply (Islam *et al.*, 2011). Water retention capacity increased for about 171 to 402 per cent when polymers are incorporate in coarse sand (Johnson, 1984). Karimi reported that addition of a polymer to peat decreased water stress and increased the time to wilt. The incorporation of SAP with soil improved the

soil physical properties (El-Amir *et al.*, 1993), enhanced seed germination, seedling emergence, crop growth and yield (Yazdani *et al.*, 2007) and reduced the irrigation requirement of plants (Blodgett *et al.*, 1993). The use of hydrophilic polymer materials as a regulator of nutrient release was helpful in reducing undesired fertilizer losses while sustaining vigorous plant growth.

Mulching has been proved to be useful material in conserving moisture and enhancing the productivity of maize. Leaf mulch also provides benefit regarding increasing infiltration rate, lowers the soil temperature and improves fertilizer availability and increase crop yield (Dushouyu *et al.*, 1995). Organic mulches resulted in enhanced soil water status and enhanced plant canopy regarding biomass, root growth, leaf area index and grain yield, which subsequently improve water and nitrogen uptake and their use efficiencies with reducing runoff and evaporation losses. The studies made to understand the combined application of superabsorbent polymers with locally available organic mulches were lacking. Apart from this the physiological basis for improvement of yield of crops when applied with SAP and mulching were need to be understood in detail. With the above facts in view, the present investigation is carried out.

Materials and Methods

A field experiment was conducted during *Kharif* 2017 at Zonal Agricultural and Horticultural Research Station, Babbar farm, Hiriyyur. The station is situated at 13° 94' 38" North latitude and 76° 61' 61" East longitude, with an altitude of 630 meters above means sea level. It comes under Agro-Climatic Region-10 and Central Dry Zone (Zone-IV) of Karnataka. The soil of the experimental site is vertisol with alkaline pH (8.41), low in organic carbon (0.19 %) and available

nitrogen (258kg ha⁻¹), medium in available P₂O₅ (35 kg ha⁻¹) and exchangeable K₂O (315 kg ha⁻¹). The experiment consisted of 10 treatments *viz.*, Maize with the recommended package (T₁), Maize with soil application of pusa hydrogel @ 2.5 kg ha⁻¹(T₂), Maize with soil application of commercial hydrogel @ 2.5 kg ha⁻¹ (T₃), Maize with soil application of pusa hydrogel @ 5.0 kg ha⁻¹(T₄), Maize with soil application of commercial hydrogel @ 5.0 kg ha⁻¹ (T₅), T₂ + mulching with pongamia green leaf @ 4.0 t ha⁻¹ (T₆), T₃ + mulching with pongamia green leaf @ 4.0 t ha⁻¹(T₇), T₄ +mulching with pongamia green leaf @ 4.0 t ha⁻¹ (T₈), T₅ + mulching with pongamia green leaf @ 4.0 t ha⁻¹(T₉) and Maize with mulching with pongamia green leaf @ 4.0 t ha⁻¹ (T₁₀). These treatments were tested in a randomized block design with three replications. The plot size of 3.6 m x 3.0 m was used. The recommended dose of fertilizer (65:40:40 kg of NPK ha⁻¹) for each treatment was applied by using urea, SSP and MOP fertilizers. The basal dose of fertilizers (50 % N and 100 % P and K) were applied at the time of sowing and remaining 50 % N was applied as a top dress at 30 DAS through urea by applying to the base of individual plants. The required quantity of hydrogel was applied to the rows at a depth of 8-10 cm before sowing and mixed with soil. A maize hybrid CP-818 was sown in furrows at a spacing of 30 cm between plants and 45 cm between rows. Immediately after sowing, pongamia green leaf mulch @ 4 t ha⁻¹ was applied by uniformly spreading over the field.

Five fully expanded leaves per treatment from areas of the canopy exposed to sunlight were selected at random and tagged for assessing the physiological parameters. The observations were recorded at 30, 60 and 90 DAS for analyzing chlorophyll a, chlorophyll b, total chlorophyll content and chlorophyll stability index. The chlorophyll content of leaves was measured by using Lichtenthaler

and Wellbum (1983) method. The pigments from 0.1 g of fresh leaf weight were extracted by using acetone 80%. Filter paper filtered extracts and the absorbance of samples was measured at 645, 652 and 663 nm by UV-visible spectrophotometer. Chlorophyll a, b and total chlorophyll content were calculated by the following formula and expressed as mg g⁻¹ fresh weight.

$$\text{Chlorophyll 'a'} = 12.7 (A_{663}) - 2.69(A_{645}) \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll 'b'} = 22.9 (A_{645}) - 2.69(A_{663}) \times \frac{V}{1000 \times W}$$

$$\text{Total chlorophyll} = 20.2(A_{645}) + 8.02(A_{663}) \times \frac{V}{1000 \times W}$$

Where,

A = Absorbance of corresponding wavelength (nm)

W = weight of the leaf material taken (g)

V = volume made up (ml)

Chlorophyll stability index (CSI) was assessed according to the method suggested by Murthy and Majumber (1962) and expressed as a percentage. CSI is calculated by using the following formula.

$$\text{CSI} = \frac{\text{Total chlorophyll content (after boiling)}}{\text{Total chlorophyll content (before boiling)}} \times 100$$

The crop was harvested at maturity by observing the maturity symptoms. Harvested matured cobs from the net plot were dried, threshed and weighed. Further, the plot yield was converted into yield per hectare and expressed as quintal per hectare.

The data on physiological parameters and yield were subjected to statistical analysis and was done as per the methodology suggested

by Gomez and Gomez (1984). Wherever the treatment differences were significant, the results have been discussed based on critical differences at $p=0.05$. The treatment differences being significant to have been denoted by '*'. Carl Pearson's correlation coefficient, as well as simple linear regression, was done by using Microsoft Excel by using data analysis add-in module.

Results and Discussion

Kernel yield of maize ($q\ ha^{-1}$)

The kernel yield of maize as influenced by the application of superabsorbent polymers alone and also in combination with pongamia green leaf mulch is presented in Figure 1. Kernel yield of maize was significantly affected by the application of superabsorbent polymers alone and also in combination with pongamia green leaf mulch. Kernel yield was found superior in commercial hydrogel rather than pusa hydrogel. Soil application of commercial hydrogel @ $5\ kg\ ha^{-1}$ + mulching with pongamia green leaf @ $4\ t\ ha^{-1}$ recorded highest kernel yield ($93.20\ q\ ha^{-1}$) which was significantly higher over rest of the treatments. Soil application of commercial hydrogel alone @ $5\ kg\ ha^{-1}$ has also recorded yield ($75.68\ q\ ha^{-1}$) on par with the combined use of hydrogel and pongamia leaf mulch. Similar on par yield levels of maize is also observed with use of commercial hydrogel @ $2.5\ kg\ ha^{-1}$ along with pongamia leaf mulch @ $4\ t\ ha^{-1}$ ($83.51\ q\ ha^{-1}$) and application of pusa hydrogel @ $2.5\ kg\ ha^{-1}$ along with pongamia leaf mulch @ $4\ t\ ha^{-1}$ ($81.11\ q\ ha^{-1}$). Significantly lower kernel yield was noticed when maize was grown with the recommended package ($64.03\ q\ ha^{-1}$). Even though maize crop experienced moisture stress during critical stages like a knee-high stage, tasseling, cob initiation and soft dough stage (grain growth and filling), application of hydrogel @ $5\ kg\ ha^{-1}$ + mulching with pongamia green leaf @ $4\ t\ ha^{-1}$ has recorded

significantly higher yield. It may be attributed to a reduction in the surface evaporation from the soil due to mulching coupled with supersorbing properties of the hydrogel which absorbs the water and releases it slowly to the growing plants as per the crop needs. The positive effect of superabsorbent polymers in increasing the yields was reported by Khadem *et al.*, (2010), Gunes *et al.*, (2016) and Kumari *et al.*, (2017) in maize.

Chlorophyll stability index (%)

The chlorophyll stability index of maize as influenced by drought management options is presented in Figure 1. Soil application of commercial hydrogel @ $5\ kg\ ha^{-1}$ + mulching with pongamia green leaf @ $4\ t\ ha^{-1}$ recorded significantly higher chlorophyll stability index (83.65 %, 82.43% and 80.92 % at 30, 60 and 90 DAS respectively). The same was on par with soil application of pusa hydrogel @ $5.0\ kg\ ha^{-1}$ + mulching with pongamia green leaf @ $4.0\ t\ ha^{-1}$ (82.80 %, 81.19% and 79.30 % at 30, 60 and 90 DAS respectively) and soil application commercial hydrogel @ $2.5\ kg\ ha^{-1}$ + mulching with pongamia green leaf @ $4.0\ t\ ha^{-1}$ (81.24 %, 79.58% and 76.68% at 30, 60 and 90 DAS respectively). Whereas, the significantly lower chlorophyll stability index was noticed in maize with the recommended package (76.86%, 71.98 % and 67.98 % at 30, 60 and 90 DAS respectively). The higher CSI indicates the better availability of chlorophyll and it leads to increase in photosynthetic rate, dry matter production and high productivity. In this study, maize plants showed a good response to water stress and recorded a varied range of CSI values. Severe water stress in maize with recommended package drastically reduced the CSI compared with soil application of hydrogel along with pongamia leaf mulch. This decrease in CSI might be due to degradation of chlorophyll producing proteolytic enzymes such as chlorophyllase, which is responsible for degradation.

Table.1 Chlorophyll ‘a’, chlorophyll ‘b’, and total chlorophyll (mg g⁻¹ fresh weight) of maize as influenced by drought management options at different growth stages

Treatments	Chlorophyll ‘a’ (mg g ⁻¹ fresh weight)			Chlorophyll ‘b’ (mg g ⁻¹ fresh weight)			Total chlorophyll (mg g ⁻¹ fresh weight)		
	30DAS	60DAS	90DAS	30DAS	60DAS	90DAS	30DAS	60DAS	90DAS
T ₁ : Maize with recommended package	1.69	1.52	1.37	0.60	0.60	0.53	2.28	2.12	1.90
T ₂ :Maize with soil application of pusa hydrogel @ 2.5 kg ha ⁻¹	1.76	1.54	1.39	0.69	0.62	0.55	2.45	2.16	1.94
T ₃ : Maize with soil application of commercial hydrogel @ 2.5 kg ha ⁻¹	1.79	1.63	1.42	0.74	0.67	0.56	2.53	2.30	1.98
T ₄ : Maize with soil application of pusa hydrogel @ 5.0 kg ha ⁻¹	1.84	1.69	1.48	0.77	0.69	0.59	2.61	2.38	2.06
T ₅ :Maize with soil application of commercial hydrogel @ 5.0 kg ha ⁻¹	1.86	1.71	1.50	0.78	0.71	0.60	2.65	2.42	2.11
T ₆ :T ₂ + Mulching with pongamia green leaf @ 4.0 t ha ⁻¹	1.89	1.74	1.53	0.79	0.72	0.62	2.68	2.45	2.15
T ₇ :T ₃ + Mulching with pongamia green leaf @ 4.0 t ha ⁻¹	1.90	1.78	1.56	0.80	0.74	0.63	2.70	2.52	2.20
T ₈ :T ₄ + Mulching with pongamia green leaf @ 4.0 t ha ⁻¹	1.95	1.79	1.64	0.83	0.75	0.67	2.78	2.54	2.32
T ₉ :T ₅ + Mulching with pongamia green leaf @ 4.0 t ha ⁻¹	1.96	1.84	1.69	0.84	0.77	0.70	2.80	2.61	2.39
T ₁₀ :Maize with pongamia green leaf mulch @ 4.0 t ha ⁻¹	1.81	1.66	1.45	0.75	0.68	0.58	2.56	2.33	2.03
F test	*	*	*	*	*	*	*	*	*
S. Em (±)	0.04	0.04	0.03	0.02	0.01	0.01	0.05	0.05	0.04
C.D. at 5%	0.11	0.12	0.09	0.06	0.04	0.04	0.16	0.15	0.13

Fig.1 Kernel yield and chlorophyll stability index of maize as influenced by drought management options

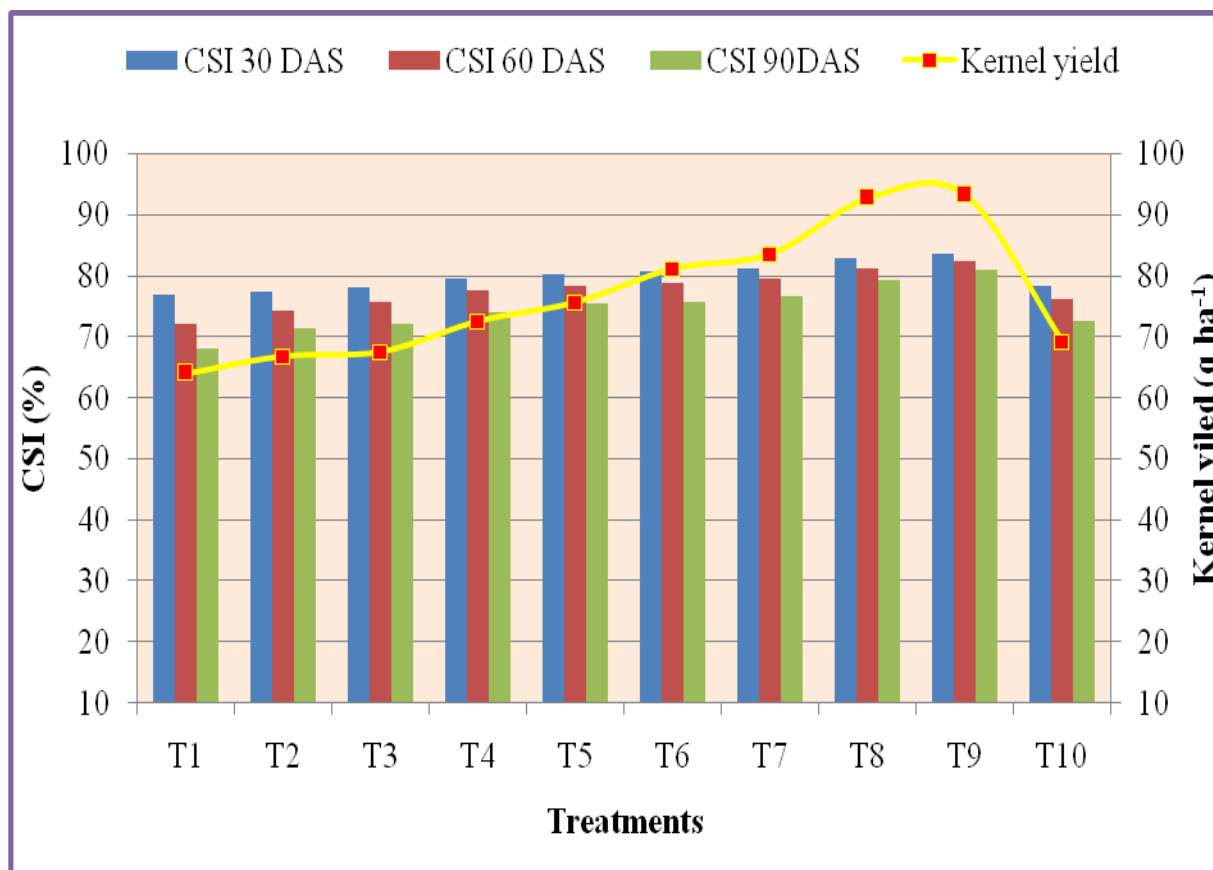
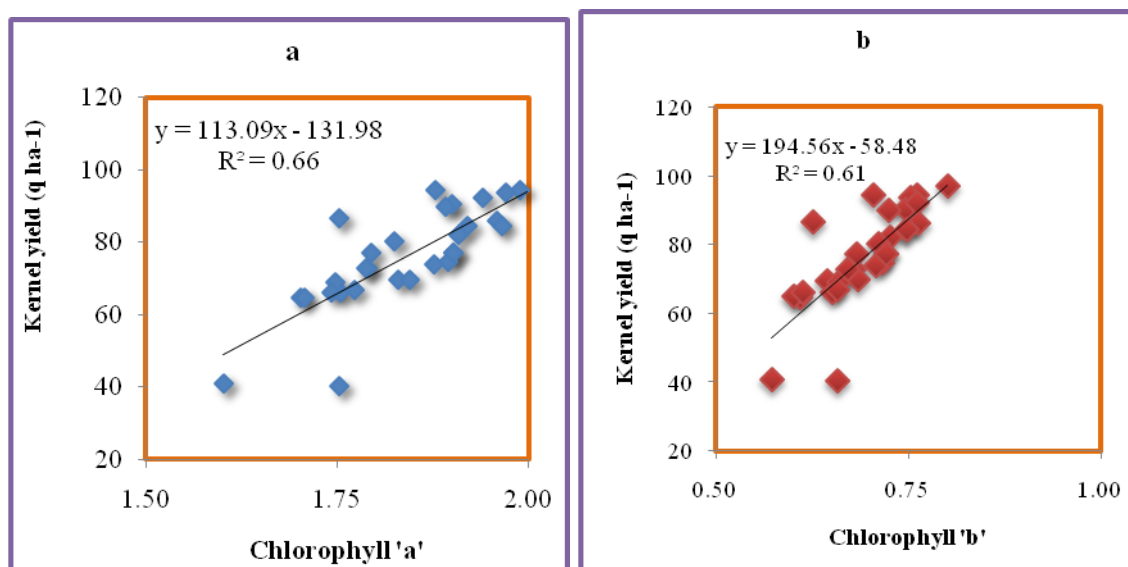
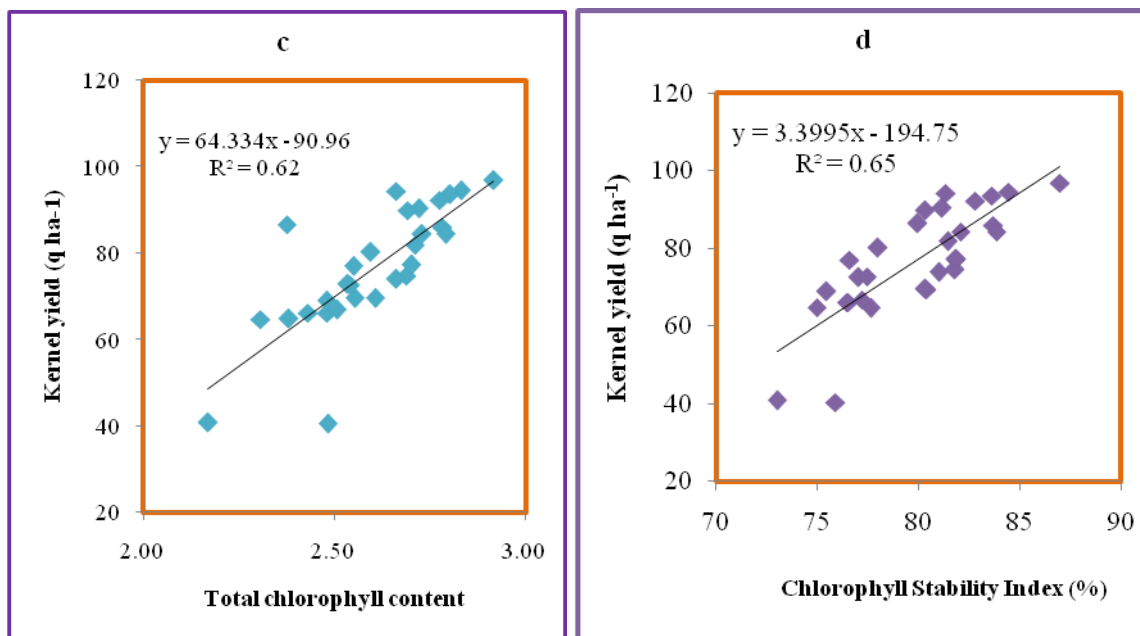


Fig.2 Relationship between Kernel yield with (a) Chlorophyll 'a', (b) Chlorophyll 'b', (c) Total chlorophyll content and (d) chlorophyll stability index





Also, under water deficit, the cell membrane is subjected to changes, such as an increase in permeability and leakage of cell solutes, which affect the stability of chlorophyll. El-Sharkawi and Salama (1977) also observed lower values for CSI under severe water stress condition and explained the cause for the degradation of chlorophyll due to low soil water status. In the present study also severe stressed plants had lower values for CSI, which indicated that chlorophyll is sensitive to water stress.

Chlorophyll ‘a’, ‘b’ and total chlorophyll content

The data on chlorophyll a, chlorophyll b and total chlorophyll content of maize as influenced by drought management options at different growth stages are presented in table 1. Soil application of commercial hydrogel @ 5 kg ha⁻¹ + mulching with pongamia green leaf @ 4 t ha⁻¹ recorded significantly higher chlorophyll ‘a’ (1.96, 1.84 and 1.69mg g⁻¹ fresh weight at 30, 60 and 90 DAS respectively), chlorophyll ‘b’ (0.84, 0.77 and 0.70 mg g⁻¹ fresh weight at 30, 60 and 90 DAS respectively) and total chlorophyll

content (2.80, 2.61 and 2.39 mg g⁻¹ fresh weight at 30, 60 and 90 DAS respectively). The treatment found on par with soil application of pusa hydrogel @ 5.0 kg ha⁻¹ + mulching with pongamia green leaf @ 4.0 t ha⁻¹ and soil application commercial hydrogel @ 2.5 kg ha⁻¹ + mulching with pongamia green leaf @ 4.0 t ha⁻¹. Whereas, significantly lower chlorophyll ‘a’ (1.69, 1.52 and 1.37 mg g⁻¹ fresh weight at 30, 60 and 90 DAS respectively), chlorophyll ‘b’ (0.60, 0.60 and 0.53 mg g⁻¹ fresh weight at 30, 60 and 90 DAS respectively) and total chlorophyll content (2.28, 2.12 and 1.90 mg g⁻¹ fresh weight at 30, 60 and 90 DAS respectively) was noticed in maize with recommended package. Application of hydrogel @ 5 kg ha⁻¹ coupled with pongamia green leaf mulch @ 4t ha⁻¹ has recorded significantly higher chlorophyll ‘a’, ‘b’, total chlorophyll as well as chlorophyll stability index compared to the maize grown at the recommended package of practices. Further, the correlation and regression also confirm the positive relationship (Fig. 2) of these physiological parameters with kernel yield of maize. Hence, application of hydrogel along with pongamia green leaf mulching has helped the maize

plants to avoid the possible effect of moisture deficit on growth as well as yield. The present findings corroborate the findings of (Mohammadkhani and Heidari, 2007, Sairam, 1994, Kraus, *et al.*, 1995 and Pastori and Trippi, 1992).

Drought management options maintained the favorable conditions for the growth of maize under drought stress. The results of the study indicated that soil application of commercial hydrogel at 5.0 kg ha⁻¹ + mulching with pongamia green leaf at 4 t ha⁻¹ resulted in the highest yield of 93.20 q ha⁻¹ and it was found better than other treatments. Application of hydrogel along with pongamia green leaf mulch had a positive effect on maize yield, favored the physiological activities and increased the survivability of maize plants under drought stress. Thus the use of hydrogel along with pongamia green leaf mulch could be an effective means of maize production under rainfed conditions.

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