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Efficacy of Hydrogels under Sensor Based Irrigation on Soil Nutrient Status of Tree Mulberry

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Authors' contributions

This work was carried out in collaboration among all authors. Authors PHM, KGB, KSV and FS performed the conceptualization of research of the manuscript. Authors GGK and DCH did the conceptualization and contribution of experimental materials and designing of the experiment. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out to study the efficacy of hydrogels under sensor-based irrigation on soil nutrient status of tree mulberry during 2022-23. The experiment was laid out in Randomized Complete Block Design (RCBD) with nine treatment combinations and three replications, observations were recorded at 30th, 45th and 60th Days after Pruning (DAP) and pooled data of five crops were analyzed. The hydrogels were applied during beginning of first crop. Main plot included two different types of hydrogels *viz.,* Pusa hydrogel (T_1- Pusa hydrogel @ 1 kg/ac, T_2- Pusa

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hydrogel @ 2 kg/ac, T_3- Pusa hydrogel @ 3 kg/ac and T_4- Pusa hydrogel @ 4 kg/ac) and Zeba hydrogel (T_5- Zeba hydrogel @ 3 kg/ac, T_6- Zeba hydrogel @ 4 kg/ac, T_7- Zeba hydrogel @ 5 kg/ac, and T_8- Zeba hydrogel @ 6 kg/ac) and T9-control without any hydrogel. Among hydrogels, Zeba hydrogel @ 5 & 6 kg/ac (T_7 and T_8) exhibited ideal pH (6.73), EC (0.27 d Sm^{-1}) and OC (0.43%). The major nutrients *viz* Nitrogen, Phosphorus and Potassium (282.03, 40.78 and 231.35 kg/ha) and secondary nutrients *viz* Calcium, Magnesium and Sulphur (2.87 c. mol/kg, 2.32 c. mol/kg and 7.68 mg/kg) has recorded significantly on the application of Zeba hydrogel @ 6 kg/ac. The micronutrient content was significantly higher in soil collected from T_8 which received Zeba hydrogel @ 6 kg/ac with Zn, Fe, Cu and Mn of 2.50, 20.97, 3.80 and 23.78 mg/kg respectively,

Keywords: Tree mulberry; sensor based irrigation; hydrogels; soil nutrient status.

1. INTRODUCTION

“Mulberry foliage is the sole food for the silkworm (*Bombyx mori*, L.) is a perennial crop which can be maintained for many years and following the recommended package of practices and water management are the imperial factors for producing quality leaf. The quality of mulberry leaves is critical to the sericulture industry's performance as it determines the economics. Moisture content in mulberry leaves improves ingestion, digestion and also the conversion of nutrients in silkworm, and provide the maximum output. Water content in mulberry leaves is considered as one of the criteria in estimating the leaf quality. The improvement of leaf quality and the productivity of leaves is immediately required for the sustainability of cocoon crops” [1].

“In Karnataka, about 95.0 percent of the mulberry gardens are under the irrigated condition, even though borewell water is a common source of irrigation, its availability is getting scarce day by day due to quick groundwater depletion which often leads to the difficulty to irrigate their mulberry gardens according to the requirements” [2]. “Water in the soil-plant system is a necessary medium for the distribution of nutrients through the plant, works as a solvent for biochemical reactions, represents as a medium of distribution for solutes and helps in temperature regulation as well as a source of hydrogen in photosynthesis” [3].

“Among all the agronomic inputs, irrigation water has highest impact on mulberry leaf quantity and quality. In sensor-based drip irrigation system, water is applied at frequent intervals over the soil to irrigate a limited area around the plant. Soil moisture sensors can be connected to the existing irrigation system controller” [4]. The sensor measures the soil moisture content in the targeted root zone before scheduled irrigation event and bypasses the cycle if the soil moisture is above the specific threshold. Hanson and Orloff [5], examined that “when the sensors are in the root zone at various points they aid in determining the acceptability of irrigation and actual. depth of irrigation to be given”.

“Mulberry requires about 1.5- 2.0 acre inches of water per irrigation at an interval of 6 - 12 days depending upon the type of soil and seasons. About eight number of irrigations are required per crop of 65-70 days’ duration to achieve the maximum leaf yield. Thus counting the annual requirement of irrigation water for five crops is about 75 acre inches of water equal to 1875 mm rainfall distributed equally @ 36 mm per week or 5-6 mm per day. But 80 per cent of average annual rainfall of 1,160 mm is received in 4-5 months in our country” [6,7].

“Hydrogels are also called as hydrophilic gels or super absorbent polymers and they are categorized into different groups, such as naturally occurring, semi-synthetic or synthetic. Most of these polymers can retain 332-465 times of water to its weight and release them slowly during stress under soil” [8]. “Hydrogels are subjected to swelling due to its hydrophilic nature on coming in contact with water and release nearly 95 per cent of stored water available for crop absorption. The process of retaining water and releasing the same by super absorbent gels may last for two to five years depending on the soil environment and cultivation process. However, ultimately in due course of time, they breaks down into CO2, water, ammonia and potassium ions without any residue, thus making it environment friendly” [9]. Hydrogels also act as soil ameliorant or conditioner by improving porosity, bulk density, soil permeability, compaction, infiltration rate, *etc*.

“When the superabsorbent hydrogel polymers are incorporated in moist soil, it becomes swollen after absorbing and storing a large quantity of water and nutrients within a short period, and allows the absorbed water and nutrients within it slowly to the soil, mitigating the water and nutrient requirements of the plant especially when the drought stress condition around the root zone periphery prevails. The peculiar water-nutrient reservoir and lending characteristics of the hydrogel polymers for the soil-plant system have been widely applied in the agricultural domain for substantial water and nutrient saving and ecological restoration [10].

2. MATERIALS AND METHODS

The experiment was conducted during 2022-23 in well-established V1 tree mulberry garden at IFS demonstration plot, All India Coordinated Research Project - Agroforestry Unit, University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bengaluru. The field is located at a latitude of 12°58′ N, and longitude of 77°35′ East and at an altitude of 930 m above mean sea level in the Eastern Dry Zone (Zone-5) of Karnataka. For all other perennial crops, the recommended dosage of Pusa hydrogel is 1-2.5 kg per acre (acrehttps://vikaspedia.in/agriculture/crop-production/advanced-technologies/applications-of-super-absorbent-polymers-in-agriculture) and Zeba hydrogel is 5 kg per (https://www.upl-ltd.com/in/crop-protection/water-conservation/zeba). Based on that, the experiment was established with nine treatment combinations *viz.,* Pusa hydrogel (T1- Pusa hydrogel @ 1 kg/ac, T2- Pusa hydrogel @ 2 kg/ac,T3- Pusa hydrogel @ 3 kg/ac and T4- Pusa hydrogel @ 4 kg/ac) and Zeba hydrogel (T5- Zeba hydrogel @ 3 kg/ac, T6- Zeba hydrogel @ 4 kg/ac, T7- Zeba hydrogel @ 5 kg/ac and T8- Zeba hydrogel @ 6 kg/ac)and T9 - control without hydrogel, were laid out in RCBD design with three replications.

Hydrogels are applied at the root zone of the tree mulberry immediately after pruning. Irrigation is applied at 50 per cent DASM (Depletion of available soil moisture). All the other practices of mulberry cultivation followed as per standard package of practices [11]. Observations recorded at regular intervals till 60th day after pruning.

Soil moisture content in the soil was measured by using soil moisture indicator, moisture probe meter and single point sensors. Single point sensors were placed at 15 cm depth to ensure enough water for crop growth. These were connected to the IoT based field controller in turn to the gateway through wireless connection in order to store the data in clouds to monitor the water stored in the soil outside the area [12].

Soil moisture indicator was developed by Sugarcane Breeding Institute, Coimbatore which works on principle of resistance but, the depiction will be in the form of colour as given in Table 1(https://sugarcane.icar.gov.in/index.php/soil-moisture-indicator/).

The data on growth parameters at 30th, 45th and 60th DAP of mulberry crop were recorded in each treatment on randomly selected five plants from each net plot and mean value was worked out. The experimental data collected on growth components of plant were subjected to Fisher's method of Analysis of Variance (ANOVA) as outlined by Panse and Sukhatme [13].

2.1 Estimation of Chemical Properties of Soil

The chemical properties in soil and plant were determined by following the standard procedure as follows: List 1.

2.2 Soil pH and Electrical Conductivity

"Soil pH was estimated in 1:2.5 soil water-suspension, using pH meter" [14]. "The clear supernatant of the soil water suspension was removed and the Electrical conductivity (EC) was measured using conductivity bridge" [14].

2.3 Soil Organic Carbon

The wet oxidation process was used to estimate soil organic carbon [15].

Table 1. Indicator readings and soil moisture status

Colour of LED	Soil moisture percentage	Soil moisture status	Inference
Blue	75-100%	Ample moisture	No need of irrigation
Green	50%	Sufficient moisture	Immediate irrigation not required
Yellow	25%	Low moisture	Irrigation advisable
Red	<25%	Very low moisture	Immediate irrigation necessary

List 1. Chemical properties in soil and plant

Parameters	Methods	References
Soil analysis		
pH (1:2.5)	Potentiometric method	Jackson [14]
EC (dS m^{-1})	Conductometric method	Jackson [14]
Organic carbon (%)	Wet oxidation method	Walkley and Black [15]
Available N (kg ha^{-1})	Alkaline permanganate method	Subbiah and Asija [16]
Available P2O5 (kg ha^{-1})	Olsen's Method	Jackson [14]
Available K2O (kg ha^{-1})	Flame photometer Method	Jackson [14]
Exchangeable Ca (c.mol/kg)	Versanate titration Method	Jackson [14]
Exchangeable Mg (c.mol/kg)	Versanate titration Method	Jackson [14]
Available S (mg kg^{-1})	Turbido metric Method	Black [17]
DTPA extractable Fe, Mn, Zn and Cu (mg kg^{-1})	Atomic absorption spectrophotometry	Lindsay and Norwell [18]

2.4 Available Nitrogen

"Soil of 5 g was distilled with 25 ml of 0.1N KMnO4 and 25 ml of 2.5 per cent NaOH. During distillation the ammonia released was trapped in 4 per cent boric acid containing mixed indicator and titrated against standard H2SO4 and the available nitrogen was expressed in kg/ha" [16].

2.5 Available Phosphorus

"The available phosphorus present in the soil was extracted with Olsen's reagent. The extracted phosphorus content was then estimated by Ascorbic acid reduced blue color method. The intensity of blue color was read in spectrophotometer" [14].

2.6 Available Potassium

"The available potassium in the soil was extracted with neutral normal ammonium acetate solution and was estimated using flame photometer" as described by [14].

2.7 Secondary Nutrients

Calcium and magnesium were determined by the EDTA titration or Versonate-titration method [14]. Sulphur content in the di acid digested sample was estimated by turbidometric method as outlined by Black [17].

2.8 DTPA Extractable Micronutrients

The content of Zn, Fe, Cu, and Mn determined by using atomic absorption spectrophotometer with appropriate hallow cathode lamps [18].

3. RESULTS AND DISCUSSION

3.1 Soil pH

Soil pH was measured in tree mulberry garden after the completion of experiment. There was no significant difference among the treatments. However, lower pH (6.72) was observed in T_7 and T_8 among the treatment which received Zeba hydrogel @ 5 & 6 kg/ac, followed by T_6 (6.73) and highest pH (7.80) was recorded in control plot (T_9) (Table 2). Trung et al. [19] found that pH was unchanged in composted pine bark amended with PAG, but was reduced by UFRF (urea-formaldehyde resin foam) alone and UFRF plus PAG (Artificial polyacrylamide gel).The addition of FYM and integrated use of FYM with chemical fertilizers resulted in significantly higher organic carbon accumulation over inorganic fertilizers alone after harvest of maize in an alfisols [20], which could be corelated to the present findings.

3.2 Soil EC (dS m^{-1})

Significantly higher EC (0.27 dS m^{-1}) was observed in T_8 (Zeba hydrogel @ 6 kg/ac) and T_7 (Zeba hydrogel @ kg/ac), whereas, the value was also on par with that of T_6 (0.26 d Sm^{-1}), T_4 (0.26 d Sm^{-1}) and T_5 (0.25 dS m^{-1}). The lowest EC (0.25dS m^{-1}) was found in Control (T_9) (Table 2).The increase in EC (d Sm^{-1}) might be due to increased amount of K application which might have accounted for more K^+ ions in solution. The increase in electrical conductivity of soil with the increase in N and K fertigation levels was reported also by Goha and Malkout [21]. Khanday and Ali [22], revealed that amongst interactions S1F1 (flood irrigation + soil application of the 100% NPK) and S2F1 (drip irrigation + soil application of 100% NPK) resulted in the highest pH in surface and sub-surface soils, respectively. S2F4 (drip irrigation + soil application of 150% NPK) and S1F6 (flood irrigation + biofertilizer and FYM) resulted in the highest EC in 0-15 and 15-30 cm. A similar effect on CEC in the surface and sub-surface soil was shown by S2F4 (drip irrigation + soil application of 150% NPK) and S3F4 (drip Fertigation with 150% NPK + FYM) respectively. Here also the availability of more moisture in several treatments resulted in good EC, which means usage of hydrogels have succeeded in maintaining good EC at the applied soil.

3.3 Organic Carbon (%)

Organic carbon content in soil at the completion of the experiment in tree mulberry garden was significantly higher in T_8 and T_7 (0.43%) which received Zeba hydrogel @ 5 & 6 kg/ac. However, significantly lower organic carbon (0.42%) content was found in control (T_1) (Table 2). The addition of FYM and its integrated usage with chemical fertilizers have resulted in significantly higher organic carbon accumulation over inorganic fertilizers alone after harvest of maize in an alfisols was reported by Kumari et al., [20]. Also, the results were on par with findingsof Pandey and Awasthi [23] and they reported highest organic content with the application of RDF (120:60:40 NPK kg ha^{-1}) + FYM 10 t ha^{-1} in maize. The present results also expressed the similar trend. Organic carbon content of soil after harvest of pearl millet increased significantly with 100% RDF + Azotobacter + PSB or 50% RDF + 5 t FYM + Azotobacter + PSB [24].

3.4 Primary Nutrient (N, P, K) Content in Soil after the Experiment

After applied with different levels of hydrogels and completion of the experiment significantly higher soil nitrogen (282.03 kg/ha) content was found in T_8 which received Zeba hydrogel @ 6 kg/ac which was on par with that of T_7 (Zeba hydrogel @ 5 kg/ac) (281.92 kg/ha) and T_6 (Zeba hydrogel @ 4 kg/ac) (280.70 kg/ha), whereas, lowest nitrogen (278.87 kg/ha) was found in control (T_9) (Table 3). Significantly higher soil phosphorus (40.78 kg/ha) content was found in T_8 (Zeba hydrogel @ 6 kg/ac) which was on par with that of T_7 (Zeba hydrogel @ 5 kg/ac) (39.74 kg/ha), T_6 (Zeba hydrogel @ 4 kg/ac) (38.32 kg/ha) and T_4 (Pusa hydrogel @ 4 kg/ac) (38.24 kg/ha). Whereas, lowest soil phosphorus (37.02 kg/ha) was found in control (T_9). Significantly higher soil potassium (231.35 kg/ha) content was found in T_8 (Zeba hydrogel @ 6 kg/ac) which was on par with that of T_7 (Zeba hydrogel @ 5 kg/ac) (230.98 kg/ha), T_6 (Zeba hydrogel @ 4 kg/ac) (230.49 kg/ha) and T_4 (Pusa hydrogel @ 4 kg/ac) (230.11 kg/ha). Whereas, lowest soil phosphorus (227.04 kg/ha) was found in control plot (T_9) which was on par with that of T_1 (Pusa hydrogel @ 1 kg/ac) (227.16 kg/ha) and T_2 (Pusa hydrogel @ 2 kg/ac) (227.80 kg/ha). El-Hady and El-Dewiny, [25] stated that soil conditioning can improve the retentivity of NPK and keep them in available forms for growing plants. Liu et al. [26] expressed that superabsorbent slow release nitrogen fertilizer (SSRNF) exhibits good slow release properties and also possess excellent soil moisture preservation capacity, which could effectively improve the utilization of fertilizer and water resources in *Pinus pinaster*. Karimi et al. [27] observed that by using Igita, a Japan-made super absorbent, nutrient (NPK) uptake was increased by plants and also the possession of these elements in clay, loamy and sandy soil was in the amounts of 0.05, 0.1 and 0.3 per cent, respectively. In corn, Seyed et al. [28] reported that potassium was increased by 21 per cent and 17.6 per cent by the application of 35 per cent manure with 65 per cent of super absorbent polymer and 65 per cent manure with 35 per cent super absorbent polymer, respectively compared to control, which supports the present investigation. In *Pennisetum glaucum*, Leila et al. [29] reported application of zeolite increased the nitrogen content significantly (0.05%) as compare to control (0.042%) by preventing from its leaching. Dabhi et al. [30] reported that super absorbent polymers influenced optimum use of fertilizers in cash crops in arid and semi-arid regions. The soil organic C, available N, P and K were significantly influenced due to different treatments. The favourable soil conditions might have helped in the mineralization of soil N leading to its higher build-up in different treatments. An increase in available P might be due to release of organic acids *viz*. maleic and citric acid on decomposition of organic manures which helps in solubilization of unavailable P. An increase in available Kdue to the addition of organic manures may be ascribed to the reduction of K fixation and release of K due to interaction of organic matter with clays, besides the direct K addition to the soil [31]. Incorporation of FYM along with fertilizers enhanced the available N content in post-harvest soil as compared to control. Increase in available N may be attributed to mineralization of FYM [32], which was also confirmed in the present study. The

Table 2. Efficacy of hydrogels under sensor-based irrigation on soil properties

Treatments	pH	EC (dsm-1)	OC (%)
Before Experiment	6.80	0.25	0.42
T_1	6.78	0.25	0.42
T_2	6.76	0.25	0.42
T_3	6.75	0.25	0.42
T_4	6.73	0.26	0.43
T_5	6.73	0.25	0.42
T_6	6.73	0.26	0.43
T_7	6.72	0.27	0.43
T_8	6.72	0.27	0.43
T_9	6.80	0.25	0.42
F test	NS	NS	NS
S Em±	0.03	0.05	0.02
CD @5%	-	-	-
CV %	3.02	4.44	4.68

Table 3. Efficacy of hydrogels under sensor-based irrigation on major nutrient status in post-harvest soil

Treatments	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Before Experiment	276.36	36.26	225.35
T_1	278.07	37.09	227.16
T_2	278.62	37.33	227.80
T_3	279.14	37.91	228.54
T_4	280.38	38.24	230.11
T_5	279.54	38.12	228.96
T_6	280.70	38.32	230.49
T_7	281.92	39.74	230.98
T_8	282.03	40.78	231.35
T_9	278.87	37.02	227.04
F test	**NS**	*	**NS**
S.Em±	2.72	0.07	1.19
CD @5%	-	0.20	-
CV %	2.17	5.79	1.16

polymer functions in absorption desorption cycles of water and nutrients. Application of zeba gel @ 37.5 kg ha-1 in tomato was resulted in enhancing nutrient NPK use efficiency (70.2, 11.8 and 76.1% respectively). Due to hydrogel application the nutrient and water holding capacity of soils and growing media is kept in optimal conditions [33]. The trend of the present results follows in similar way.

3.5 Secondary Nutrient (Ca, Mg and S) Content in Soil after the Experiment

The maximum calcium (2.87 c. mol/kg) content was recorded in T_8 (Zeba hydrogel @ 6 kg/ac) among all the treatments and the value is on par with T_7 (Zeba hydrogel @ 5 kg/ac) (2.82 c. mol/kg), T_6 (Zeba hydrogel @ 4 kg/ac) (2.70 c. mol/kg) and T_4 (Pusa hydrogel @ 4 kg/ac) (2.67 c. mol/kg). Whereas, lowest soil calcium (2.38 c. mol/kg) was found in control (T_9) which was on par with that of T_1 (Pusa hydrogel @ 1 kg/ac) (2.45%) and T_2 (Pusa hydrogel @ 2 kg/ac) (2.50 c. mol/kg). Significantly higher magnesium (2.32 c. mol/kg) content was observed in the T8 which received Zeba hydrogel @ 6 kg/ac after 60 days after pruning of tree mulberry followed by T_7, T_6, T_4 and T_5 (2.30, 2.26, 2.23 and 2.18 c. mol/kg, respectively). However, lowest soil magnesium (1.75 c. mol/kg) was found in control plot (T_9) which was on par with that of T_1 (Pusa hydrogel @ 1 kg/ac) (1.77%) and T2 (Pusa hydrogel @ 2 kg/ac) (1.97%). The Sulphur (7.68 mg/kg) content was significantly abundant in T8 which received Zeba hydrogel @ 6 kg/ac after 60 days after pruning of tree mulberry garden. Whereas, less Sulphur (6.06 mg/kg) content was found in control (T_9) (Table 4).

Table 4. Efficacy of hydrogels under sensor-based irrigation on secondary nutrient status in post-harvest soil

Treatments	Calcium (c. mol/kg)	Magnesium (c. mol/kg)	Sulphur (mg/kg)
Before Experiment	2.30	1.71	6.03
T_1	2.45	1.77	6.11
T_2	2.50	1.97	6.16
T_3	2.56	2.06	6.20
T_4	2.67	2.23	6.84
T_5	2.62	2.18	6.59
T_6	2.70	2.26	7.09
T_7	2.82	2.30	7.15
T_8	2.87	2.32	7.68
T_9	2.38	1.75	6.06
F test	*	*	*
S.Em±	0.03	0.06	0.18
CD @5%	0.11	0.09	0.54
CV %	3.30	7.15	6.32

The increase in exchangeable Ca and Mg content of soil might be due to release of these nutrients from added organic sources which was confirmed even by Sanjiv kumar [34].

3.6 Micronutrient (Zn, Fe, Cu and Mn) Content in soil after the Experiment

Among all the treatments, the micronutrient content was significantly higher in soil collected from T_8 which received Zeba hydrogel @ 6 kg/ac with Zn, Fe, Cu and Mn of 2.50 mg/kg, 20.97 mg/kg, 3.80 mg/kg and 23.78 mg/kg, respectively, followed by T_7 (2.21 mg/kg, 20.88 mg/kg, 3.74 mg/kg and 22.62 mg/kg), T_6 (1.96 mg/kg, 20.55 mg/kg, 3.61 mg/kg and 21.85 mg/kg), T4 (1.77 mg/kg, 20.25 mg/kg, 3.56 mg/kg and 21.26 mg/kg) and T_5 (1.68 mg/kg, 19.04 mg/kg, 3.45 mg/kg and 21.09 mg/kg). Whereas, lowest Zn, Fe, Cu and Mn content was observed (1.46 mg/kg, 18.39 mg/kg, 3.28 mg/kg and 20.16 mg/kg) in control (T_9) which was on par with that of T_1 (1.52 mg/kg, 18.22 mg/kg, 3.35 mg/kg and 20.12 mg/kg) and T_2 (1.58 mg/kg, 18.66 mg/kg, 3.39 mg/kg and 20.64 mg/kg) on 60 days after pruning (Table 5). Ahmed et al. [35] reported that addition of more concentration of hydrogels raises CEC, and thereby increases the retention of soil nutrients which corroborates even the present study. The dissolved fertilizer diffuses from the hydrogel network and releases slowly into the soil by the dynamic exchange of free water between swollen hydrogel and soil. The rate of fertilizer release increases with the increase in swelling. Eventually when the hydrogel swelling reaches equilibrium the fertilizer release rate also becomes constant [36], which could be the

Table 5. Efficacy of hydrogels under sensor-based irrigation on micro nutrient status in post-harvest soil

Treatments	Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Mn (mg/kg)
Before Experiment	1.42	18.25	3.25	20.12
T_1	1.52	18.42	3.35	20.23
T_2	1.58	18.66	3.39	20.64
T_3	1.63	18.90	3.43	20.80
T_4	1.77	20.25	3.56	21.26
T_5	1.68	19.04	3.45	21.09
T_6	1.96	20.55	3.61	21.85
T_7	2.21	20.88	3.74	22.62
T_8	2.50	20.97	3.80	23.78
T_9	1.46	18.39	3.28	20.16
F test	*	*	NS	*
S. Em±	0.07	0.45	0.33	0.60
CD @5%	0.20	1.30	-	0.85
CV %	8.87	5.14	12.03	6.35

reason for more quantum of micronutrients compared to control. Also the highest copper, boron, iron and manganese content was observed in the treatment having FYM @ 10 t ha^{-1} + 100% RDF followed by treatment receiving FYM @ 10 t ha^{-1} + 50% RDF [37].

4. CONCLUSION

It can be concluded that climate change affected the distribution of rainfall affecting the plant growth due to unavailability of moisture and nutrients during critical stages, especially in dry land areas. That demands to cultivate crops with good agricultural practices. Application of hydrogel enhances maximum water holding capacity, prevent runoff and evaporation loss of water from the soil. Besides, loss of nutrient through leaching and volatilization can be prevented which in term plants are benefited for their growth and development.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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