International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(2): 529-533

Received: 06-01-2019
Accepted: 10-02-2019

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Hydrogel: To enhance crop growth and available water under moisture stress condition of young coffee (cv. C X R)

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Abstract
An investigation was carried out to study the response of hydrogel on growth and water stress parameters of young coffee in field at Central Coffee Research Institute, coffee Research Station, during the year September 2016 and 2017. The trial was laid out in randomized complete block design with three replications. Data pertaining to growth parameters showed significant difference among the treatments during the both the years of study and in pooled means. Among the different levels of hydrogel applied at main field, plants received hydrogel at 30g/plant + Compost @ 2 kg/plant registered significantly highest growth parameters viz., plant height, number of leaves, number of primaries, length of primary, stem diameter, no. of nodes on main stem and bush spread (30.90 cm, 19.76, 2.50, 10.14 cm, 0.90 cm and 33.87 cm, respectively in 2016; 76.11cm, 38.56, 9.89, 29.39 cm, 1.12 cm and 48.61 cm, respectively in 2017 and 53.51 cm, 29.16, 6.20, 19.77 cm, 1.01 cm and 41.24 cm, respectively in pooled means) and least was recorded in control (20.93cm, 7.75, 1.08, 5.98 cm, 0.54cm and 14.76 cm, respectively in 2016; 49.50 cm, 25.11, 5.56, 15.89 cm, 0.71 cm and 31.22 cm, respectively in 2017 and 35.22 cm, 16.43, 3.32, 10.94 cm, 0.63 cm, 22.99 cm, respectively in pooled means). Similarly, plants received hydrogel at 30g/plant + Compost @ 2 kg/plant registered significantly higher soil moisture content (16.74 to 21.34 %) and relative water content (72.69 to 83.42 %) which was followed by plants received hydrogel at 20g/plant and at 10g/plant. However, the significantly lower soil moisture content (7.78 to 14.21 %) and relative water content (54.11 to 57.81%) was recorded under control on pooled basis. Study results showed that application of hydrogel along with compost is effective tools in increasing water holding capacity of soil so it may become a practically convenient and economically feasible option in coffee plantation areas for establishment of young coffee plants.

Keywords: young coffee, hydrogel, compost, growth parameters, soil moisture content

Introduction

Coffee is primarily cultivated as a rainfed crop worldwide and planting of coffee on steep hill sloppy regions with lack of supplementary irrigation and application of nutrients, cause gradual decrease in their productivity. In the coffee tracts of South India, the South-West monsoon provides more than 60% rain and rest is from North-East monsoon. The dry period usually consists of 4-5 months from November onwards (Coffee Guide, 2014) [3]. The most important factor which limits the establishment and production of coffee even in well managed estates is the long dry period. In addition, irregular monsoon and changing climatic condition are the major constraints in coffee production in India. These constraints are expected to become increasingly important in several coffee growing regions due to the climatic fluctuation and water shortage. Implementation of proper water management practices such as micro- irrigation, fertigation, supplementation of super absorbent polymers (SAPs) etc., are considered as best ways to manage moisture stress during the drought period to improve soil moisture and water holding capacity of soil in coffee growing estates.

Hydrogel (Super absorbent polymer) is a water retaining, biodegradable, amorphous polymer which can absorb and retain water at least 400 times of its original weight and make at least 95 per cent of stored water available for crop absorption. When it is mixed with the soil, it forms an amorphous gelatinous mass on hydration and is capable for retaining it for longer period in soil and releasing water slowly as per crop root demand. The improvement in growth and yield attributing characters and yield of different field, ornamental and vegetable crops has been reported with the application of hydrogel. Agricultural hydrogels are not only used for water saving in irrigation, but they also have tremendous potential to improve physicochemical and biological properties of the soil. Hence application of hydrogel will be a fruitful option for increasing agricultural production with sustainability in water-stressed environment.

Research evidences suggest that application of 1.5 liters of polymer solution (composed of 1.5 kg of polymer diluted in 400 liters of water) at the time of new planting can reduce the mortality of coffee plants in the main field. (Pieve *et al*., 2013) [12]. Another investigation revealed that application of 100 gm absorbent recorded significantly higher yield of *Citrus limon* and increased the water holding capacity of the soil from 28.74 to 34.63 per cent. The increased yield might be due to the fact that the soil was wet for a longer time which enhanced the microbial activity as well as reducing the fruit drop due to water stress. It was also observed that absorbent was able to retain available water for the plant up to fifteen days after irrigation (Pattanaaik *et al*., 2015) [11].

Studies pertaining to the application of hydrogel in young coffee plants at main field had not been attempted coffee grown region. Hence, keeping in view the above facts, investigation was carried out to evaluate the response of hydrogel on growth and water stress parameters of young coffee plants in main field.

Material and Methods

The present investigation was carried out during the September 2016 and 2017, to study the response of hydrogel on growth and water stress parameters of young coffee in the main field. The experiment was conducted at D division of Central Coffee Research Institute, Coffee Research Station, Balehonnur, Karnataka in a sandy clay soil. The trial was laid out in Randomized complete block design (RCBD) replicated thrice the treatment combinations comprised; T_1 – Control, T_2 – Hydrogel 10 g /plant, T_3 – Hydrogel 20 g /plant, T_4 – Hydrogel 30 g /plant, T_5 – Hydrogel 10 g /plant + Compost @ 2 kg/plant, T_6 – Hydrogel 20 g /plant + Compost @ 2 kg/plant & T_7 – Hydrogel 30 g /plant + Compost @ 2 kg/plant. The cultivar used for the trial was C x R clones (young plants), planted at Spacing of 8'x 6'ft. The hydrogel treatments were imposed with applied hydrogel along with compost near the root zone of seedling of planting pit. Moisture holding properties of the experimental site were estimated by using ponding method for each 15 cm soil depth up to 30 cm by following the standard procedures (Dastane *et al.,* 1967) [4]. Analysis of initial physical properties of experimental site indicated the bulk density was 1.36 and 1.54 g cm^3 at 0 – 15 cm and 15 – 30 cm depth respectively. The moisture percentage at saturation was 45.96 % and 43.31% at 0-15 and 15-30 cm depth respectively. Similarly, the moisture percentage at field capacity 30.43 % and 26.54% at 0-15 cm and 15-30 cm depth respectively. The hoase irrigation practice was followed in all the treatments for scheduling of irrigation as an when the soil moisture content reaches below the threshold level. Three representative plants in each plot were randomly selected and tagged. All the successive growth observations during the crop growing period were recorded both the years of study. The plant height was measured from the base of the stem to the tip of longest leaf and the average of three plants was worked out. Leaf area determination and leaf area was measured by recording length and breadth of leaf. Stem diameter measured by using vernier calliper instrument and bush spread was measured by using the simple measuring tape.

For moisture measurement (%) regular soil samples were collected (15 days interval) prior to each hoase irrigation at threshold level *i.e.,* whenever plant shows visual symptoms of drooping or wilting as per the treatment schedule and oven dried for 72 hours at 105^o C till constant weight is achieved. Then dry weight of the samples were assessed and expressed in percentage. Similarly, relative water content of leaf was calculated to examine coffee plant reaction to water deficit stress. For this purpose, top-most fully expanded leaves of three plants from second and third row plant between 1300 – 1500 hours were sampled. Each sample was placed in a pre-weighed air tight vial. Vials were weighed in the laboratory to obtain leaf sample weight (F), after which the sample was immediately hydrated by placing them in distilled for about 24 hours to full turgidity under normal room light and temperature. After hydration the samples were taken out of water and well dried of surface moisture quickly and lightly with filter/tissue paper and immediately weighed to obtain fully turgid weight (TW). Samples were then oven dried at 80^0 C for 72 hours and weighed (after being cooled down in a desiccator) to determine dry weight (DW). All weighing was done to the nearest mg.

Leaf Relative Water Content (RWC) was determined according to the methods of Barrs and Weatherley (1962) [2], based on the following equation:

$$\text{RWC}\ (\%) = \frac{(\text{FW} - \text{DW})}{(\text{TW} - \text{DW})}\ \text{x}\ 100$$

Where,

FW = Fresh weight of leaves,

DW = Dry weight of leaves after drying at 80 °C for 72 hours,

TW = Turgid weight of leaves after soaking in water

The data on various parameters studied during the course of investigation were statistically analyzed as suggested by Gomez and Gomez (1984) [7]. Wherever, statistical significance was observed, critical difference (CD) at 0.05 level of probability was worked out for comparison. Non - significant comparison was indicated as 'NS'.

Results and Discussion

Effect of hydrogel on growth parameters of young coffee

Observation on growth parameters viz., plant height, number of leaves, number of primaries, length of primary, stem diameter, no. of nodes on main stem and bush spread recorded and it showed significant influence among the different levels of hydrogel during both the years of study (Table 1). Among the different treatments, plants received hydrogel at 30g/plant + Compost @ 2 kg/plant (T_7) recorded significantly higher growth parameters (30.90 cm, 19.76, 2.50, 10.14 cm, 0.90 cm and 33.87 cm, respectively in 2016; 76.11cm, 38.56, 9.89, 29.39 cm, 1.12 cm and 48.61 cm, respectively in 2017 and 53.51 cm, 29.16, 6.20, 19.77 cm, 1.01 cm and 41.24 cm, respectively in pooled means) over rest of the hydrogel treatments except that it was on par with plants received hydrogel at 20g/plant + Compost @ 2 kg/plant (T_6) (27.84 cm, 16.64, 2.11, 9.88 cm, 0.85 cm and 31.54 cm, respectively in 2016; 72.33 cm, 37.11, 7.89, 26.00 cm, 1.00 cm and 45.11cm, respectively in 2017 and 50.09 cm, 26.88, 5.00, 17.94 cm, 0.93 cm and 38.33 cm, respectively in pooled means). Further, the difference in growth parameters between T_3 (Hydrogel 20 g /plant) and T_4 (Hydrogel 30 g /plant) were found to be non significant. Other hand, lowest growth parameters were registered in T_1 (Control - Compost @ 2 kg/plant) during both the years of study (20.93 cm, 7.75, 1.08, 5.98 cm, 0.54cm and 14.76 cm, respectively in 2016; 49.50 cm, 25.11, 5.56, 15.89 cm, 0.71 cm and 31.22 cm, respectively in 2017 and 35.22 cm, 16.43, 3.32, 10.94 cm, 0.63 cm, 22.99 cm, respectively in pooled means). This finding was in agreement with El-Hard *et al*, (2009) [5]; he reported that the beneficial effect of mixtures of organic matter and hydrogel exceeds that of each conditioner when solely added. Leaf area indicates good idea of the photosynthetic capacity of the plant and decreased leaf area is an early response to water deficit. With an increase in hydrophilic polymer, there was significant increase in leaf area. Hydrophilic polymer increases the turgor pressure inside the cells by maintaining sufficient amount of water as per crop requirement and thus causing increase in leaf area and other related growth parameters (Yazdani *et al.*, 2007) [14]. Khadem *et al*, (2010) [9] also reported that application of 65% cow manure and 35% superabsorbent polymer (26 tha^{-1} cow manure + 70 kg ha^{-1} super absorbent polymer) increased grain yield by 16.2% as compared to control.

Variation of soil water content with crop growth stages

Variation in soil moisture over the crop growing season as by different hydrogel levels in pooled mean is presented in Figure 1. Young coffee plants received hydrogel at 30g/plant + Compost @ 2 kg/plant (T_7) had maintained appreciably higher soil moisture content (16.74 to 21.34 %) over entire crop growing season on pooled basis, since it received higher hydrogel levels along with compost @ 2 kg/plant. The next best treatment was plants received hydrogel at 20g/plant + Compost @ 2 kg/plant (12.80 to 19.74 %) (T_6) which was closely followed by plants received hydrogel at 10g/plant + Compost @ 2 kg/plant (10.64 to 19.23 %) (T_5). On the other hand solely application of hydrogel treatments viz., plants received hydrogel at 10g/plant (8.23 to 16.32 %) (T_2), plants received hydrogel at 20g/plant (8.80 to 17.85%) (T_3) and plants received hydrogel at 30g/plant (10.00 to 18.55 %) (T_4) recorded appreciably lower relative water content during entire crop growing. Whereas, the lowest soil moisture content (7.78 to 14.21 %) was registered in the control (T_1) during both the years of study. This finding was in agreement with Al-Rahim *et al*, (2007) [1]; he reported that application of 0.6% hydrogel concentration prolonged the time of water loss from the soil by about 66% and the seedlings grown in 0.6% hydrogel mixed soil survived three times as long as those grown in the control soil, however, was statistically at par with 0.4 % hydrogel concentration. Also he collaborated that hydrogel applied to sandy loam soils increased the amount of available moisture in the root zone and water holding capacity resulting in longer intervals between irrigations. Similarly, Kramer (1988) reported that application of superabsorbent polymer could conserve water thereby increasing the soil's capacity for water storage, ensuring more available water, relative water content in leaves and plant growth increased under water stress.

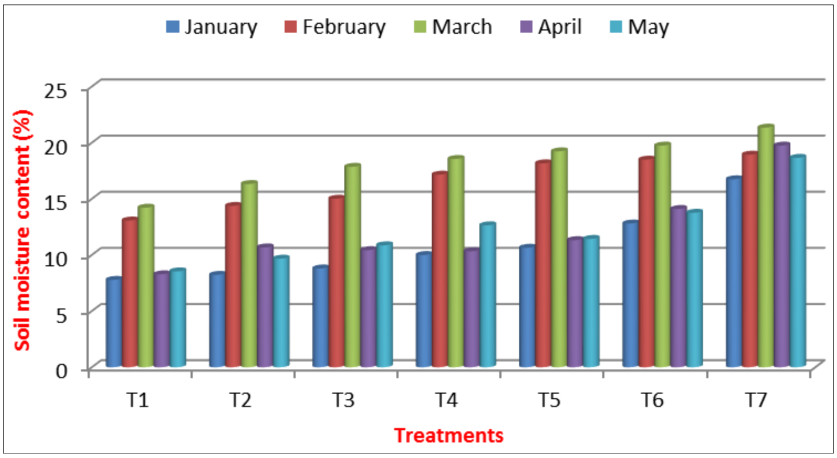

Fig 1: Influence of different levels of hydrogel on soil moisture content

Table 1: Growth parameters of young coffee as influenced by different levels of hydrogel *during 2016, 2017 and Pooled means*

Treatments	Plant height (cm)			Number of leaves			Number of primaries/branch			Length of primary (cm)			Stem diameter (cm)			Bush Spread (cm)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	20.93	49.50	35.22	7.75	25.11	16.43	1.08	5.56	3.32	5.98	15.89	10.94	0.54	0.71	0.63	14.76	31.22	22.99
T_2	22.25	58.61	40.43	8.00	27.56	17.78	1.28	6.44	3.86	7.00	20.06	13.53	0.62	0.87	0.75	17.87	32.67	25.27
T_3	23.73	64.87	43.95	9.92	30.67	20.30	1.78	6.56	4.17	8.10	22.56	15.33	0.69	0.93	0.81	21.76	37.44	29.60
T_4	24.18	70.89	47.54	10.08	31.76	20.92	1.83	7.33	4.58	9.13	23.11	16.12	0.75	1.00	0.88	25.76	40.61	33.19
T_5	25.38	71.39	48.39	13.65	33.56	23.61	1.89	6.78	4.34	9.70	25.94	17.82	0.80	0.98	0.89	29.65	43.28	36.47
T_6	27.84	72.33	50.09	16.64	37.11	26.88	2.11	7.89	5.00	9.88	26.00	17.94	0.85	1.00	0.93	31.54	45.11	38.33
T_7	30.90	76.11	53.51	19.76	38.56	29.16	2.50	9.89	6.20	10.14	29.39	19.77	0.90	1.12	1.01	33.87	48.61	41.24
SEm+-	1.06	1.96	1.93	0.89	1.24	0.97	0.07	0.61	0.43	0.47	1.10	0.57	0.02	0.03	0.04	1.09	1.82	1.39
CD at 5%	3.26	6.04	5.94	2.75	3.82	3.01	0.23	1.90	1.33	1.46	3.39	1.78	0.08	0.12	0.12	3.26	5.62	4.28

Influence of hydrogel on relative water content (%) of young coffee

Variation in relative water content of young coffee over the crop growing season as by different hydrogel levels in pooled mean is presented in Figure 2. Among the different levels of hydrogel, plants received hydrogel at 30g/plant + Compost @ 2 kg/plant (T_7) maintained relatively higher relative water content (72.69 to 83.42 %) throughout the crop growth period over the rest of the treatments. Similarly, application of hydrogel along with compost viz., plants received hydrogel at

20g/plant + Compost @ 2 kg/plant (72.48 to 77.16%) (T_6) and plants received hydrogel at 10g/plant + Compost @ 2 kg/plant (71.87 to 75.95 %) (T_5) maintained appreciably higher relative water content as compared to solely application of hydrogel treatments viz., plants received hydrogel at 10g/plant (56.62 to 65.43%) (T_2), plants received hydrogel at 20g/plant (61.47 to 66.17%) (T_3) and plants received hydrogel at 30g/plant (63.19 to 69. 59%) (T_4). Likewise control - Compost @ 2 kg/plant (T_1) maintained relatively lower relative content (54.11 to 57.81%) during both the years of study.

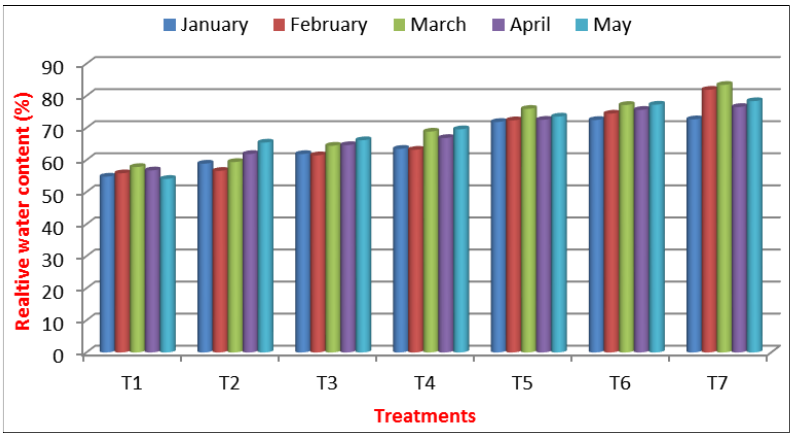

Fig 2: Influence of different levels of hydrogel on relative water content of young coffee.

Relative water content is probably the most appropriate measure of plant water status in terms of the physiological consequence of cellular water deficit accurately indicating the balance between water input, absorbed water by plant and evapotranspiration rate (Farquhar *et al.*, 1989) [6]. This influences the ability of the plant to recover from stress and consequently affects growth and water stress parameters (Hsiao *et al.*, 1984; Kramer and Boyer, 1995) [8, 10]. Therefore, these variations in relative water content could be traced to concurrent variation in soil moisture content (Figure 1) (Techawongstin *et al.*, 1993) [13]. A good Correlation existed between RWC versus soil moisture content with a calculated Determination Coefficient of R^2 = 0.736 significant at P=0.01 (Figure 3).

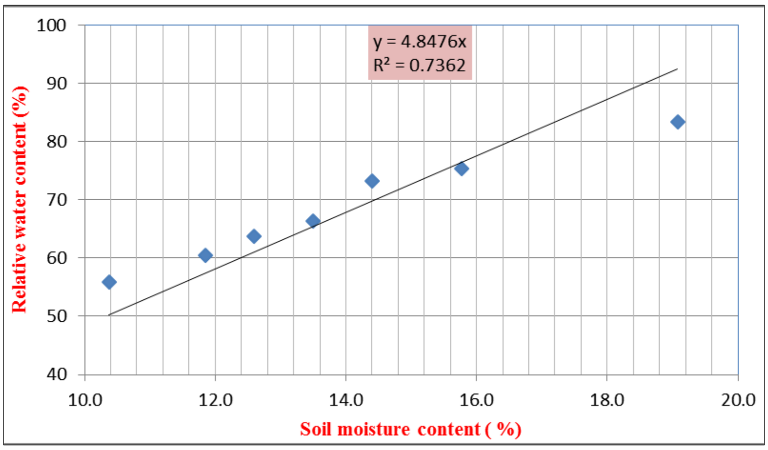

Fig 3: Regression of RWC on soil moisture content (%)

Conclusion

Water is an important input for realizing high crop productivity; however, it is becoming the most limiting factor for crop production. Water conservation is a key step to attain sustainable agriculture growth, development and productivity. The problem of optimal capitalization and recovery of water from any source should be seen as a major goal of scientific research. Water absorbing materials have been reported to be effective tools in increasing water holding capacity and leaf relative content of young coffee. Hence hydrogels may become a practically convenient and economically feasible option in water-stressed coffee grown areas for increasing productivity with environmental sustainability.

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