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Performance of hydrogel on post planting behavior of young coffee cv. CXR

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ABSTRACT

A field trial was conducted to know the effect of hydrogel on growth, survival and performance of young coffee seedlings (cv. CX R) under field condition. Prior to planting in the main field seedlings were exposed to the hydrogel at polybag stage and the best performed treatment seedlings were taken for planting in the main field. At polybagstage, among the different levels of hydrogel,seedlings received hydrogel 1 gm/ per polybag performed well compared to rest of the treatments. At field, observation on growth parameters showed significant difference among the different levels of hydrogel. Similarly, data on soil moisture and relative water contents (leaf) indicated that experiment plot planted with the seedlings which were pre-exposed to hydrogel 1 gram per polybag/ seedling at nursery level recorded higher soil moisture and relative water contents as compared to plots planted with normal seedlings. Further, among the different levels of hydrogel applied at main field, plants received hydrogel10 g/plant/year registered significantly higher soil moisture (20.04, 18.54 and 17.24 %) and relative water contents (77.58, 75.64 and 70.97 %) followed by plants received hydrogel 5 g plant^{-1} year^{-1} (18.38, 16.75 and 15.29 % and 74.31, 70.94 and 68.85 %),respectively during all the month of observation. Interaction effect showed higher soil moisture and relative water contents in seedling treated with hydrogel [1 g poly bag^{-1} (Seedling)] with plants received hydrogel 10 g plant^{-1} year^{-1} at main field. So it can be concluded that application of hydrogel conserved 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 condition.

***Keywords*:** Coffee, hydrogel, growth parameters, relative water content and soil moisture content

Coffee is one of the important plantation crops grown in India. Among the two major species of coffee grown in India namely arabica (*Coffea arabica*) and robusta (*Coffea canephora),* robusta is more susceptible to drought andresponds well to irrigation than arabica. India is governeddefinite rainfall pattern which is spread over 4-6 months followed by dry season of 4- 5 months. For successful establishment of young plantations, coffee should be irrigated during dry months to a depth well below the root zone and the intervals between two irrigations should be long enough without causing serious wilting to young coffee. This encourages deep rooting and also improves the anchorage of trees. If adequate water is available, young coffee can be irrigated at every 15-20 days interval during dry months with one inch irrigation. However, sprinkler irrigation encourages excessive weed growth. Suitable measures like cover crops etc can be adopted to suppress weed growth. In areas of limited water supply, it is advisable to go for sub-soil injection or hose irrigation once in 15 days with about 4-5 litres of water per plant (Coffee Guide, 2014). Research evidences suggest that problems associated with traditional micro- irrigation and irrigation techniques can be reduced by the application of polymers without compromising the crop yield (Oraee *et al*., 2013 and Barakat *et al.*, 2015).

Hydrogel (super absorbents) is one of the most popular, having also been used to reduce water runoff and increase infiltration rates in the field of agriculture, in addition to increasing water holding capacity for agricultural applications. The use of hydrophilic polymers, to improve soil water retention properties and thus, crop productivity is attracting considerable interest. Hydrogel absorbs water after rain or applied irrigation from soil and water which it releases back to the soil as and when the plant demands. This function is particularly important during dry seasons as the hydrogel will hold soil moisture in water limited areas and feed the necessary water into the root system of the plant. The efficiency of the technology is highly suited for farmers growing crops under rainfed and limited water availability areas. Application of hydrogel reduces frequency of irrigation in almost all the crops including cereals, pulses, vegetables and flowers, thus reducing time and money spend on irrigation, labour and water costs.

Studies pertaining to the application of hydrogel in young coffee seedlings at main field had not been attempted coffee growing regions. Hence, keeping in view the above facts, investigation was carried out to evaluate the performance of hydrogelon survival, growth and performance of young coffee seedlings (cv. CX R) in the main field.

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MATERIALS AND METHODS

A field trial was conducted at D Division CCRI farm to study the effect of hydrogel on growth, survival and performance of coffee seedlings under field condition.The experiment was designed in such way that the seedlings may get the exposure to the hydrogel during all the stages of crop development *viz.*, nursery bed, polybag stage and planting in to the main field. For the imposition of the hydrogel treatment at the nursery bed stage two nursery beds were raised with a dimension of one meter in length, one meter in breadth and 15cm in height. Before sowing the seeds, one bed was treated with hydrogel at the rate of 25 g per square meter area and another bed was treated without hydrogel (control). The bed was treated with hydrogel was irrigated once in 3 days, whereas the bed without hydrogel was irrigated daily (either morning or evening). Observations on total number of seeds germinated and number of seeds to 50% germination was recorded.

Further, 45 days old nursery seedlings (seedlings raised with and without hydrogel at nursery level) were selected separately and transplanted into the polybags as per the treatments viz., 1g, 2g and 3g of hydrogel per poly bag (seedling) and control (without hydrogel) by adopting Randomized Block Design (RCBD) with four replications. Before transplanting of seedlings (Topy stage) into the polybags, the polybags approximately one kg capacities were filled with soil, sand and FYM with a ratio of 6:2:1 and were applied with the calculated quantity of hydrogel as per the treatments. The 45 days old coffee seedlings from non treated nursery bed were transplanted into the polybags, containing no gel (control or without hydrogel) and the seedlings of treated nursery bed (with hydrogel) were pulled off separately and transplanted into the polybags containing various levels of hydrogel (1g, 2g and 3g). The polybags which contains no gel were irrigated daily once and the polybags treated with 1g, 2g and 3g of hydrogel were irrigated alternate day, once in two days and once in three days, respectively. Observations on shoot and root parameters were recorded through destructive method of sampling. The best performed treatment seedlings at polybag stage were taken for planting in the main field.

The methodology was adopted for the field study as follows.The experimental plot was laid out in Factorial Randomized Block Design (FRBD) and replicated in thrice with following treatments on young CXR plants planted at a spacing of 6 X6 feet. The treatments comprises of two main factors: S_1 –Seedling raised with hydrogel at rate of 1 g per poly bag (Seedling)] at nursery level, S_2 – Seedlings raised without hydrogel treatment at nursery level (normal seedling) and four sub factors: F_1 –Control (without hydrogel), F_2 –5 g plant^{-1} year^{-1}, F_3 –10 g plant^{-1} year^{-1} and F_4 – Compost @ 2 kg pit^{-1}. Moisture holding properties of the experimental site were estimated for each 15 cm soil depth up to 30 cm by following the standard procedures (Dastane *et al.*, 1967). 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.Three representative plants in each plot were randomly selected and tagged. All the successive growth observations during the crop growing period were recorded. The height was measured from the base of the stem to the tip of longest leaf and the averages of three plants were worked out. Total leaf areacalculated by recording length and breadth of leaf.Length of primary measured by using the simple measuring scale.

For soil moisture measurement (%) regular soil samples were collected prior to each hose 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, rela-tive water content (%) was calculated to examine coffee plant reac-tion to water deficit stress. For this purpose, top-most fully expanded leaves of three plants from second and third row plant between 13-15 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 (FW), 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 or 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).

Relative water content of leaf (RWC) was determined according to the methods of Barrs and Weatherley (1962), based on the following equation:

$$RWC(\%) = \frac{(FW - DW)}{(TW - DW)} x100$$

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). Wherever, statistical significance was observed, critical difference (CD) at 5% level of probability was worked out for comparison. Non - significant comparison was indicated as 'NS'.

RESULTS AND DISCUSSION

Nursery bed treated with hydrogel (25 g m^{-2} area) and untreated showed non significant difference on percent seed germination (Fig. 1). However, the maximum percentage of seed germination (90%) was observed in control (without hydrogel) and also taken less number of days (35) to achieve 50 % seed germination. Whereas, nursery bed treated with hydrogel observed minimum percentage of seed germination (86.9%) and taken more number of days (40) to achieve 50% seed germination. Maximum number of seeds germinated and higher germination percentage in the treatment control (without hydrogel) could be attributed to the presence of ash covering seed coat helps in retaining and maintaining the moisture content of the bean with proper aeration in the bed throughout the germination phase, which enhanced the metabolic activity and triggers the germination process, results in earlier and better germination was achieved.

Seedlings received hydrogel at nursery bed were taken to the polybag stage and exposed to different levels of hydrogel *viz.*,1g, 2g and 3g of hydrogel per poly bag and control (without hydrogel). Recorded observation showed significant influence of hydrogel on growth parameters of coffee seedlings (Table 1). Among the different treatments, treatment T_1 (control) recorded significantly maximum plant height (40 cm), number of leaves per plant (14), stem girth (0.51cm), total nodes per plant (7) and shoot dry matter partitioning (11gm), which was on par with T_2 (1 g gel per polybag) with respect to stem girth (0.51 cm). Whereas, minimum plant height, number of leaves per plant, stem girth, total nodes per plant, tap root length, root volume and shoot and root dry matter partitioning (18 cm, 10, 0.40 cm, 5, 19cm, 6 cc g^{-1}, 4 g and 1g, respectively) was observed in treatment T_4 (3g gel per polybag). However, the parameters like tap root length, root volume and root dry matter partitioning (29 cm, 9 cc g^{-1} and 3 g, respectively) was significantly higher in treatment T_2 (1 g gel per polybag), which was found on par with treatment T_3 (2 g gel per polybag) with respect to tap root length and root volume (28 cm and 7 cc g^{-1}, respectively). Increasing levels of hydrogel has a negative effect on the growth of seedlings in the nursery for height (cm), number of leaves per plant, stem girth, total nodes per plant and shoot dry matter partitioning. This might be due to the fact that, hydrogel also absorbs water and fills the soil pores causing flooding in the polythene tubes therefore retards the growth and growth parameters of young coffee seedlings. This finding was in agreement with (Cheruiyot *et al*., 2014).

Data on growth parameters indicated that seedlings received hydrogel 1 g polybag^{-1} seedling (i.e. treatment S_1) recorded higher plant height,number of leaves,number of primaries, length of primary and total leaf area (25.05 cm,10.21, 1.94, 9.70 cm and 78.18 cm, respectively) as comparedto normal seedlings (i.e. treatment S_2) (22.72 cm, 8.20, 1.76, 8.41 cm and 74.17 cm, respectively) (Table 2). Among the different levels of hydrogel, plants received hydrogel 10g plant^{-1} year^{-1}

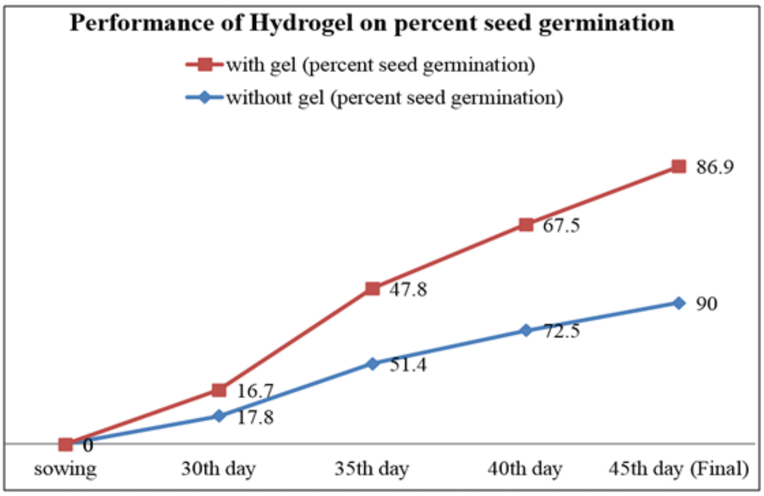

Fig. 1: Performance of hydrogel on percent seed germination

Table 1: Influence of hydrogel on growth parameters of young coffee seedlings (8 months old) in nursery

Treatments	Plant height (cm)	Number of leaves per plant	Stem girth (cm)	Total nodes per plant	Tap root length (cm)	Root volume (cc)	Dry matter partitioning (gm)	
							Shoot	Root
T_1	40	14	0.51	7	26	6	11	2
T_2	35	12	0.51	6	29	9	8	3
T_3	27	12	0.44	6	28	7	6	2
T_4	18	10	0.40	5	19	6	4	1
SEm (±)	**1.3**	**0.3**	**0.0**	**0.2**	**0.8**	**0.7**	**0.6**	**0.2**
LSD (0.05)	**3.9**	**0.8**	**0.1**	**0.5**	**2.3**	**2.0**	**1.8**	**0.5**

Table 2: Growth attributes of young coffee at different levels of hydrogel (6 MAP) in the main field

Treatments	Growth parameters				
	Plant height (cm)	Number of leaves	Number of primaries	Length of primary (cm)	Total leaf area (cm)
Hydrogel					
S_1: Seedling treated with hydrogel	25.05	10.21	1.94	9.70	78.18
S_2 : Normal seedling	22.72	8.20	1.76	8.41	74.17
SEm (±)	**0.18**	**0.04**	**0.02**	**0.08**	**0.44**
LSD (0.05)	**0.55**	**0.13**	**0.06**	**0.24**	**1.32**
Different levels of hydrogel					
F_1 : Control (without hydrogel)	22.31	8.30	1.18	6.98	56.58
F_2 : 5 g plant^{-1} year^{-1}	23.81	9.13	2.01	9.91	82.01
F_3 : 10 g plant^{-1} year^{-1}	26.38	10.48	2.41	11.25	99.71
F_4 : Compost @ 2 kg pit^{-1}	23.03	8.91	1.80	8.10	66.40
SEm (±)	**0.26**	**0.06**	**0.02**	**0.11**	**0.62**
LSD (0.05)	**0.78**	**0.18**	**0.08**	**0.34**	**1.87**
Interaction effects (S × F)					
S_1F_1	23.73	9.93	1.30	6.96	54.26
S_1F_2	24.36	10.23	2.13	10.13	87.66
S_1F_3	27.90	10.60	2.50	12.63	103.66
S_1F_4	24.20	10.06	1.83	9.10	67.13
S_2F_1	20.90	6.66	1.06	7.00	58.90
S_2F_2	23.26	8.03	1.90	9.70	76.36
S_2F_3	24.86	10.36	2.33	9.86	95.76
S_2F_4	21.86	7.76	1.76	7.10	65.66
SEm (±)	**0.37**	**0.08**	**0.04**	**0.16**	**0.88**
LSD (0.05)	**1.11**	**0.26**	**0.12**	**0.48**	**2.65**

(F_3) recorded significantly higher plant height, number of leaves, number of primaries, length of primaryand total leaf area(26.38 cm,10.48, 2.41,11.25 cm and 99.71 cm, respectively) followed by plants received hydrogel 5 g plant^{-1} year^{-1} (F_2) whereas, lowest plant height, number of leaves, number of primaries, length of primary and total leaf areawere registered in F_1 (without hydrogel) (22.31 cm, 8.30,1.18, 6.98 cm and 56.58 cm, respectively) . Interaction effect of seedlings which were pre-exposed tohydrogel with different levels of hydrogel applied at main field were significant, plant height (27.90 cm), number of leaves (10.60), number of primaries (2.50), length of primary(12.63) and total leaf area (103.66) were significantly higher in seedlings pre

Table 3: Influence of different levels of hydrogel on soil moisture content at main field

Treatments	Soil moisture content (%)		
	January	February	March
Hydrogel			
S_1: Seedling treated with hydrogel	18.31	17.15	15.74
S_2 : Normal seedling	16.51	14.65	12.96
SEm (±)	**0.11**	**0.13**	**0.11**
LSD (0.05)	**0.30**	**0.40**	**0.32**
Different levels of hydrogel			
F_1 : Control (without hydrogel)	15.14	13.70	12.15
F_2 : 5 g plant^{-1} year^{-1}	18.38	16.75	15.29
F_3 : 10 g plant^{-1} year^{-1}	20.04	18.54	17.24
F_4 : Compost @ 2 kg pit^{-1}	16.08	14.60	12.72
SEm (±)	**0.14**	**0.18**	**0.15**
LSD (0.05)	**0.43**	**0.57**	**0.46**
Interaction effects (S × F)			
S_1F_1	15.75	14.65	12.86
S_1F_2	19.31	17.75	16.72
S_1F_3	21.42	20.65	19.76
S_1F_4	16.74	15.54	13.65
S_2F_1	14.53	12.76	11.45
S_2F_2	17.44	15.76	13.87
S_2F_3	18.66	16.43	14.73
S_2F_4	15.42	13.67	11.79
SEm (±)	**0.19**	**0.27**	**0.23**
LSD (0.05)	**0.61**	**0.81**	**0.65**

exposed to hydrogel in poly bag nursery [1 g poly bag^{-1} (seedling)] with plants received hydrogel 10 g plant^{-1} year^{-1} (S_1 F_3) at main field.

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. This finding was in agreement with Yazdani *et al.* (2007).

Data on soil moisture indicated that plants receivedhydrogel 1 g polybag^{-1} seedling at polybag stage (i.e. treatment S_1) recorded higher soil moisture content (18.31, 17.15 and 15.74 %) as compared to normal seedling (i.e. treatment S_2) (16.51, 14.65 and 12.96%) , respectively during all the months of observation (Table 3). Among the different levels of hydrogel applied at main field, plants received hydrogel 10 g plant^{-1}year^{-1} (F_3) registered significantly higher soil moisture content (20.04,18.54 and 17.24 %) and the next best treatment was plants received hydrogel 5 g plant^{-1}year^{-1} (F_2) during all the months of observation. Whereas, the lower soil moisture content was recorded in the control plot (without hydrogel) during all the months of observation. Interaction effect of seedlings which were pre-exposed to hydrogel 1 g poly bag^{-1}] (S_1) with different levels of hydrogel applied at main field were significant, the soil moisture content was significantly higher in seedlingspre exposed to hydrogel in poly bag nursery [1 g polybag^{-1} (seedling)] with plants received hydrogel 10 g plant^{-1} year^{-1} at main field (S_1 F_3) (21.42, 20.65 and19.76 %), respectively during all the months of observation.This might be due to 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.Similar finding was reported by Al-Rahim *et al.* (2007) and Narjary *et al.* (2012) 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.

Table 4: Influence of different levels of hydrogel on relative water content at main field

Treatments	**Relative water content (%)**		
	January	**February**	**March**
Hydrogel			
S_1: Seedling treated with hydrogel	69.10	66.13	63.12
S_2 : Normal Seedling	65.23	63.29	59.50
SEm (±)	**0.65**	**0.34**	**0.65**
LSD (0.05)	**1.59**	**1.06**	**1.96**
Different levels of hydrogel			
F_1 : Control (without hydrogel)	57.20	54.00	50.95
F_2 : 5 g plant^{-1} year^{-1}	74.31	70.94	68.85
F_3 : 10 g plant^{-1} year^{-1}	77.58	75.64	70.97
F_4 : Compost @ 2 kg pit^{-1}	59.76	58.25	54.55
SEm (±)	**0.75**	**0.50**	**0.93**
LSD (0.05)	**2.26**	**1.51**	**2.78**
Interaction effects (S ×F)			
S_1F_1	59.64	55.87	52.65
S_1F_2	75.76	72.16	68.53
S_1F_3	79.63	76.64	72.18
S_1F_4	61.76	59.87	55.76
S_2F_1	54.76	52.14	49.25
S_2F_2	72.87	69.73	65.84
S_2F_3	75.53	74.65	69.73
S_2F_4	57.76	56.64	53.34
SEm (±)	**1.71**	**0.71**	**1.31**
LSD (0.05)	**3.19**	**2.13**	**3.93**

Seedlings planted in main field which were pre-exposed to hydrogel 1 g poly bag^{-1} (seedling)] (S_1) at polybag stage recorded higher relative water content (leaf) (69.10,66.13and 63.12 %) as compared to normal seedling (S_2) (65.23,63.29 and 59.50%), respectively during all the months of observation (Table 4). Among the different levels of hydrogel applied at main field, plants received hydrogel 10 g plant^{-1} year^{-1} (F_3) registered significantly higher relative water content (77.58, 75.64 and 70.97 %) and which was followed by plants received hydrogel 5 g plant^{-1} year^{-1} (F_2)during all the months of observation.Whereas, the lower relative water content was recorded under the control plot (without hydrogel) (F_1) during all the months of observation.Interaction effect of seedlings received hydrogel 1 g poly bag^{-1} (Seedling) (S_1) at polybag stage with different levels of hydrogel applied at main field were significant, relative water content was significantly higher in seedlings received hydrogel 1 g poly bag^{-1} (seedling) at poly bag stage with plants received hydrogel 10 g plant^{-1} year^{-1} at main field (S_1F_3) (79.63, 76.64 and 72.18 %), respectively during all the months of observation.

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). 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 (Kramer, 1988). Decrease in soil water content increases soil water tension (i.e., decreases soil water potential) and coffee plant roots experience difficulty in absorbing water thereby reducing the plant water content. This influences the ability of the plant to recover from stress and consequently affects adversely on growth of young coffee plant (Kramer and Boyer, 1995). Therefore, these variations in relative water content could be traced to concurrent variation in soil moisture content (Techawongstin *et al.*, 1993).A good correlation existed between RWC versus soil moisture content with a calculated Determination Coefficient of R^2 = 0.954 significant at P=0.01 (Fig. 2).

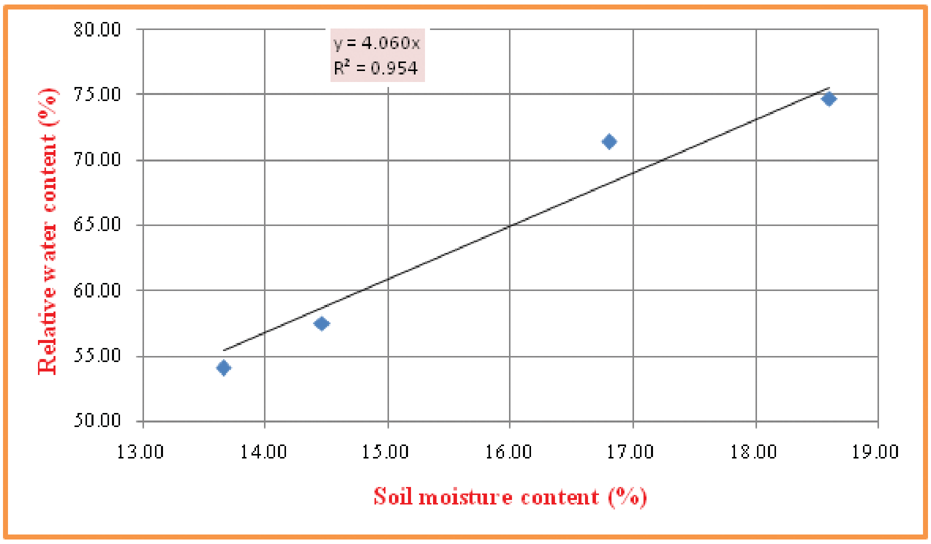

Fig. 2: Regression of relative water contentof coffee leaf on soil moisture content (%)

The problem of optimal capitalization and recovery of water from any source should be seen as a major goal of scientific research. Water will become the "cornerstone" of sustainability and the future of humanity. Water absorbing materials have been reported to be effective tools in increasing water holding capacity. Hence hydrogel may become a practically convenient and economically feasible option in coffee growing areas for efficient use of irrigation water with environmental sustainability.

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