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Effects of Organic and Inorganic Soil Conditioners on Soil Moisture in Drylands

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Abstract: Resource conservation in rainfed areas is mainly focused on *in-situ* rain water harvesting through different agronomic adoption practices. Soil conditioning with the addition of organic and inorganic substances will be an alternative to overcome the problems faced with land configuration measures. It modifies the physico-chemical properties of the soil and acts as a drought resilient mechanism during dry spells. The organic (coir pith and press mud) and inorganic (hydrogel and gypsum) soil conditioners are used to study the soil moisture variations in drylands. The addition of soil conditioners influenced the soil infiltration rate. Hydrogel (2 kg ha^{-1}) ranked highest in storing the moisture compared with other conditioners like gypsum, hydrogel (1 kg ha^{-1}), coir pith and press mud.

Keywords: *Soil conditioners, soil moisture, infiltration rate*

Introduction

India has 60% of net sown area under rainfed regions and ranks first among the rainfed agricultural countries in the world in terms of value of produce. The prominence on agricultural development in the present century has shifted to the sustainable use of land, water and plant resources in agriculture. The major aim of the present day agriculture is to maximize land and water productivity without menacing the environment and the natural resources soil and water.

Soil conditioners, both natural and synthetic, supply to provide a reservoir of soil water to plants on demand in the top soil layer where the root systems normally develop. These conditioners apart from improving the soil physical properties also serve as buffers against temporary drought stress and reduce the risk of plant failure during establishment (De Boodt 1990). New generations of soil conditioners are cross-linked polyacrylamides with 40% of the amides hydrolyzed to carboxylic groups (Yangyuoru *et al.* 2006). These polymers do not interact directly with the soil matrices but form aqueous gels and act as water reservoirs for the plant-soil system. Gypsum has been used for many years as a conditioner for sodium affected soils and it increases the water use efficiency and improves water retention and infiltration in soil as compared with control . And one of the recently developed organic soil conditioners, Coco-peat, has been observed to greatly improve the physical and chemical status of soils (Managecraft 2001). Because of high fertilizer prices and environmental concerns associated with its use and with the enhanced emphasis on commercial and organic

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farming, recent years have witnessed growing interest in utilizing coir pith in a more productive way (Prabhu and Thomas 2001). The press mud used as conditioner is rich in many plant nutrients and it also has properties to ameliorate degraded soils (Solaimalai *et al.* 2001) and the application of this organic conditioner could promote and improve the agro-ecosystem, and also represent an effective strategy for a sustainable solution (Bhosale *et al.* 2015).

Soil conditioners are the products that are applied to improve soil structure, porosity and to reduce water erosion. These conditioners impact the soil water content including water holding capacity. Soil conditioning implies improvement of the soil physical properties permitting more effective utilization of soil and water resources. Soluble conditioners undergo physico-chemical reactions with soil constituents and the application of different soil conditioners results in aggregation improvement, improved porosity and hydraulic conductivity, decreased bulk density, improved infiltration and acts as effective stabilizers of soil surface by enhancing the capacity of the soils to absorb rainfall, decrease run-off and increasing the water storage capacity of the soil. The ability of the soil to hold water rises by up to 16,500 gallons per acre for every 1% increase in organic matter (Gould 2012). The beneficial effects of amendments on soil moisture are influenced by changes in soil structure brought about by subsequent increases in soil organic carbon (Kallenbach *et al*. 2019). With all these considerations, the present research work aimed to study the influence of different soil conditioners on drylands with control treatment and its influence on soil moisture content in dry lands.

Materials and Methods

Description of study area

Kumulur (10° 56' North; 78° 49' East) in Lalgudi block, Tiruchirapalli is a semi-arid region located in Tamil Nadu and lies between and 70 m occur at an elevation of above mean sea level. The average annual rainfall obtained from meteorological station of Kumulur for 23 years (1992 to 2015) is 752.9 mm, of which 374.2 mm is received during North East Monsoon, 189 mm during South West Monsoon, 144.2 mm during summer and 45.5 mm during winter. The major share of rainfall is received during the months of October, November and December and during this period, rainfed crops are raised. The mean maximum and minimum temperature of Kumulur is 34.5 °C and 25.0 °C respectively

Soil parameters

The soil in the area was sandy clay loam with pH of 6.8, bulk density 0.89 Mg m^{-3} and infiltration rate of 9.6 cm h^{-1}. The soil had 0.25 % organic carbon and 238.9, 26 and 229 kg ha^{-1} of available N, P_2O_5 and K_2O, respectively. The field capacity was of soil 26.8 per cent and wilting point of 17.7 per cent.

Application of soil conditioners

The soil conditioners used in this study were hydrogel 1 kg ha^{-1} and 2 kg ha^{-1}, powdered gypsum, coir pith and press mud. The conditioners were applied in the surface soil by broadcasting method.

Soil Conditioners	Dose	Reference
Hydrogel	1 kg ha^{-1} and 2 kg ha^{-1}	Singh *et al.* (2018) Kumar *et al.* (2020)
Powdered gypsum	1 t ha^{-1}	Theint *et al.* (2015) Rusyanto *et al.* (2017)
Coir pith	12.5 t ha^{-1}	Rangaraj *et al.* (2007) Elayaraja and Singaravel (2009)
Press mud	37.5 t ha^{-1}	Karuppaiah and Kathiravan (2006) Mary and Anitha (2019)

Hydrogel

Hydrogel was applied at the rate of 1 kg ha^{-1} and 2 kg ha^{-1} mixed with sand. The rate of application varies to study the impact of hydrogel on water holding capacity. It absorbs water and swells up to several times than their original size and releases water into the soil over time. It also provides significant amount of retained soil moisture especially during dry period.

Powdered gypsum

Gypsum, was used as a soil conditioner to supply soluble calcium and sulphate sulphur, to absorb more water during rainfall. Gypsum creates an impact on soil and water quality and crop productivity. In areas during drought, this is extremely important to improve water infiltration rate, and hydraulic conductivity of soil for better water storage in the soil which could help crops for deeper rooting and better water-use efficiency. Gypsum was applied at the rate of 1 t ha^{-1} in present study.

Coir pith

Coir pith is a water sucking material which stores the rain water by absorbing. Coir is one of the growing substrate and it has the unique water retention quality. It is hydrophilic in nature and spreads moisture readily over the surfaces. The presence of coir pith ensures the quick and effective rewetting because of its better capillary wetting properties. Capillary property of coir pith redistributes the absorbed moisture. It acts as the soil conditioner and provides moisture during dry periods. Coir pith was applied at the rate of 12.5 t ha^{-1} at the top soil.

Press mud

A raw press mud is industrial waste from sugar mills. It is a soft, spongy, amorphous and dark brown to brownish white material, containing sugar, fibre, coagulated colloids including can-wax, aluminous inorganic salts and soil particles. Press mud is applied at the rate of 37.5 t ha^{-1} as a conditioner to retain moisture in dry lands.

Soil moisture estimation

Screw type auger was used in drawing out soil samples at two selected depths (0-15, 15-30 cm). Soil samples were collected and analyzed at weekly intervals.

Gravimetric method

Soil moisture content in the different treatments and control plot was estimated by gravimetric method. The wet soil samples drawn out were transferred to containers of known weight (w). The total weight of the wet soil sample along with the weight of the container (w_1) was noted. The containers with soil were kept in a hot air oven at a temperature of 105°C for 24 hours, so that the moisture even from the inner core of the soil sample was completely driven out by drying. The dry weight of the soil sample along with the container (w_2) was observed (Rowe 2018). Then the moisture content on dry basis was obtained as follows.

Soil moisture content on a dry weight basis (P_{dw})

$$P_{dw} = \frac{w1-w2}{w2-w} * 100$$

Results and Discussion

Effect of soil conditioners on soil moisture storage

Soil moisture storage (% dry weight) at surface soil (0-15 cm)

In the surface soil, application of hydrogel (2 kg ha^{-1}) stored the highest mean moisture content (22.2 per cent) followed by gypsum (16 per cent), hydrogel at 1 kg ha^{-1} (15.4 per cent), coir pith (12 per cent) and press mud (5 per cent) (Fig.1). The increase in moisture percentage in the hydrogel treatment might be due to the highly cross-linked polyacrylamides, which form aqueous gels with high super absorbency (Bashir *et al.* 2020). The efficiency of the hydrogels relies in that, they increase the capacity of the soil to retain moisture, improving the aeration and maintaining temperature parameters in the soil (Gales *et al.* 2012).

The moisture recorded in the hydrogel (1 kg ha^{1}) and gypsum treatments were almost same (16 and 15.4 per cent). Ramirez *et al.* (1999) reported that application of gypsum resulted in flocculation of the sediments which resulted in higher intake rate of water while Rehman *et al.* (2013) reported that addition of gypsum enhance the water infiltration and reduce the run-off resulting in the maximum soil moisture storage.

The composted coir pith and press mud recorded 12 per cent and 5 per cent higher moisture than control. The fibrous nature of the composted coir pith helped to retain higher moisture content than the press mud treatment, which contained fine particles that might have affected the infiltration rate resulting in low soil moisture storage

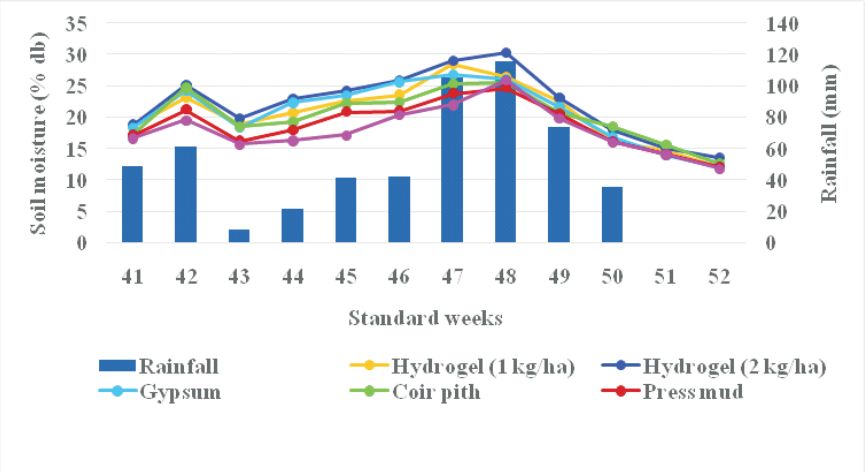

Fig.1. The rainfall and soil moisture content recorded in different soil conditioners at 0-15 cm depth.

Soil moisture storage (% db) at sub-surface soil (15 – 30 cm)

In the sub-surface soil (15-30 cm), there was not much variation in soil moisture stored among the treatments. Application of hydrogel (2 kg ha^{-1}) registered 11 per cent increase in moisture content than control. The other soil conditioners did not show any significant effect on sub-soil moisture storage (Fig.2). This may be due to the reason that the soil conditioners were applied to the surface soil which might have influenced the soil physical properties of the surface soil than the sub-surface soil.

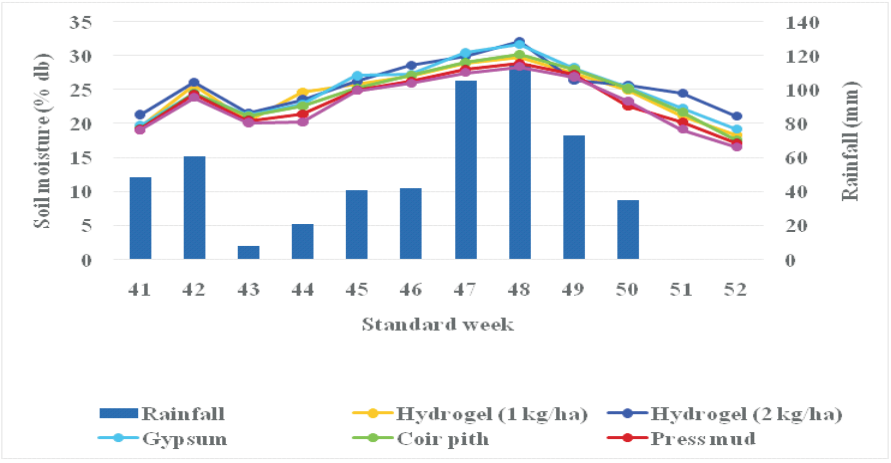

Fig.2. The rainfall and soil moisture content recorded in different soil conditioners at 15-30 cm depth.

Mean profile moisture in (0-30 cm) depth of soil

The mean profile moisture storage at 0-30 cm depth for the standard weeks (42 to 52) was calculated for selection of the best soil conditioners representing the effective root zone of most dryland crops like pulses and millets (Fig. 3).

The mean moisture storage stored in the hydrogel (2 kg ha^{-1}), hydrogel(1 kg ha^{-1}), gypsum, coir pith, press mud and control were 24.00, 22.56, 22.90, 22.25, 21.09 and 20.45 per cent respectively. Application of hydrogel at 2 kg ha^{-1} ranked first among treatments in storing the highest soil moisture which was 17.40 per cent higher compared to control and 6.88 per cent higher than hydrogel (1 kg ha^{-1}). Pattanaaik *et al. (*2015) reported that the application of 100 gram of hydrogel for a citrus plant increased the water holding capacity of the soil from 28.4 per cent to 34.63 per cent in sandy loam soils compared to control. The reason for increased soil moisture was reported that, during the water release phase of hydrogel, free pore volume would be created within the soil, offering additional space for root growth and air and water infiltration and storage. Coir pith and press mud recorded 8.80 and 3.13 per cent higher moisture than control.

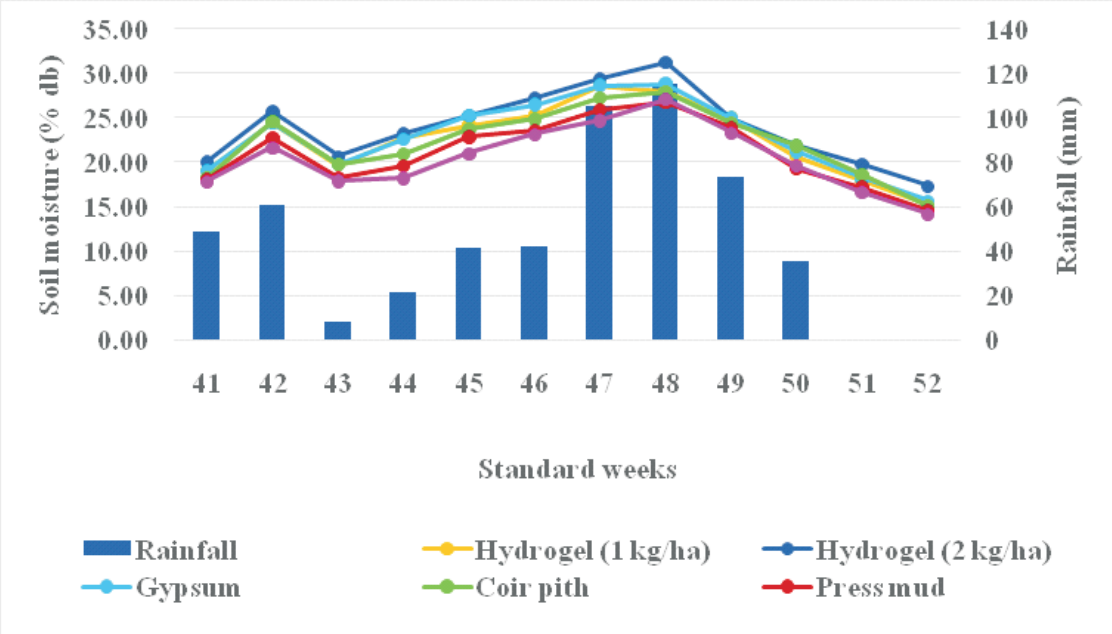

Fig. 3. Total profile moisture content

Effect of conditioners on the infiltration rate of soil

The application of conditioners in drylands to increase the moisture storage, changes the rate of infiltration in soil. The conditioners such as hydrogel (1 kg ha^{-1}, 2 kgha^{-1}), gypsum, coir pith and press mud were applied in the field. The initial infiltration rates were found to increase due to the application of soil conditioners. The observed values were 19.2, 18, 16.8, 12, 10.8 and 9.6 cm h^{-1} in hydrogel (2 kg ha^{-1}), hydrogel (1 kg ha^{-1}), gypsum, coir pith, press mud and control treatments respectively which decreased and attained a constant infiltration rate of 1.2, 1.2, 0.9, 0.9, 0.7 and 0.8 cm h^{-1} respectively. The initial infiltration rate was doubled with the application of hydrogel (2 kg ha^{-1}) followed by hydrogel (1 kg ha^{-1}) and gypsum which increased the infiltration rate by 1.88 and 1.75 times than of control (Fig 4).

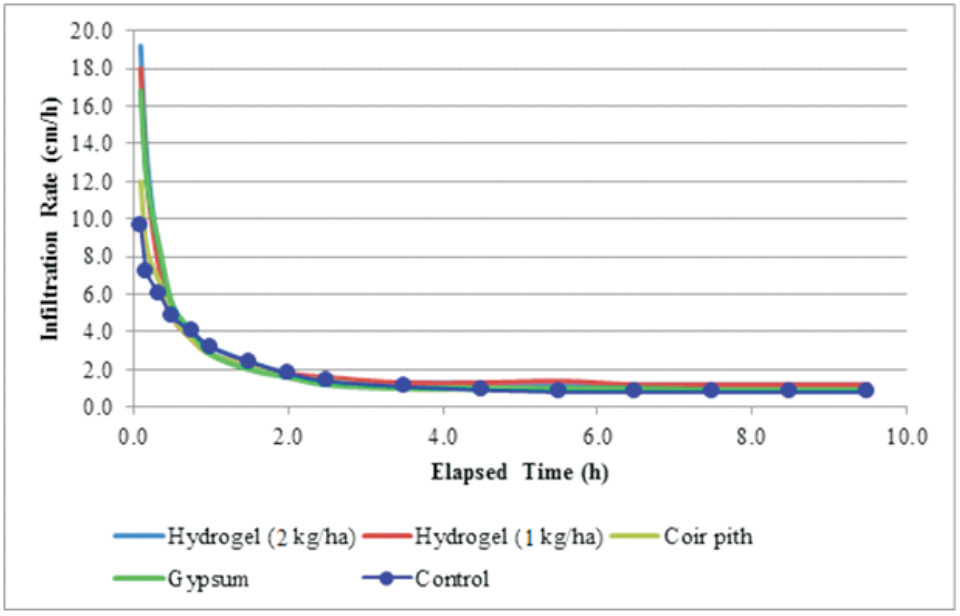

Fig. 4. Infiltration rate of different soil conditioners

Conclusion

It was observed that the superabsorbent hydrogel helps in optimization of water resources and water saving for the drylands. Hydrogel stored highest moisture in both surface and sub-surface soil, followed by the treatments having gypsum, coir pith and press mud. However, the effect of inorganic conditioners on soil properties and their longevity over a period of time needs further investigation to assess its sustainable effect on soil.

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