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Effect of suitable amendments on the water holding capacity of soils: A review

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Abstract
The amount of irrigation water to be applied in any agricultural field is directly dependent upon the water holding characteristics of soil. The water holding capacity indicates the amount of water in the soil available to the plants for optimum growth. The water holding capacity and available water determines the mobilization of various nutrients applied/present in the soil. The water use efficiency also depends upon the water holding capacity of soil. This review paper includes the scientific work done by various workers on water holding capacity of different soils. In this review study, it has been found that the soil organic matter and the soil texture are the two major factors that have a great affect on the soil water holding capacity. It is also found, that the water holding capacity of the soils was considerably increased when the soil was amended with the polymers like - sodium polyacrylate, hydro gel polymers and synthetic polymers. Also, in some cases, it has been observed that the addition of biochar and bentonite soil amendment increases the soil water holding capacity. The application of straw mulch and different tillage systems also has a significant effect on the ability of the soils to hold moisture and the available water capacity. So, from this review study, it is concluded that the addition of amendments to soil has a great effect on water holding capacity of the soil.

Keywords: Soil water holding capacity, soil texture, organic matter, soil amendments, mulching, tillage, polymers

Introduction
Irrigation is one of the critical inputs to agriculture sector and the irrigation requirement of different crops is different because of different crop characteristics, climatic conditions and soil properties. The amount of irrigation water to be applied in any agricultural field is directly dependent upon the water holding characteristics of soil. The soil water holding capacity of the soil indicates the percent of water held by the soil mass on dry weight basis.
Water holding capacity is an important characteristic for decision on scheduling irrigations. The water holding capacity determines the amount of water available to the plants for use, so that the plants can give optimum yield. The water holding capacity and available water determines the mobilization of various nutrients applied/present in the soil. The water use efficiency also depends upon the water holding capacity of soil. Also, the water holding capacity and soil available water regulates the soil temperature and helps many chemical and biological activities to occur in the soils. It also helps many micro organisms to thrive in soil. If the water holding capacity of a soil is well known, then water wastage due to over irrigation can be checked. The presence of organic matter and texture of soil greatly influence the water holding capacity of soil. This review paper includes the scientific work done by various workers on water holding capacity of different soils.

Effect of organic matter and soil texture on water holding capacity of soil
Leu *et al*. (2010) [5] conducted a study on the effect of an organic matter amendment on the change in soil water holding capacityin Sahelien environment of Africa. The research was done for the improvement of soil water holding capacity by the application of different dosages of organic matter to three types of soil, namely sandy clay loam, sandy loam and sand under Sahelien condition. A computer simulation model was used for the evaluation of the effect of organic amendments on the soil water holding capacity. On the other hand, the testing of an irrigation scheduling model was done on three selected crops i.e. maize, bean and rice, in the Ouagadougou region located in Burkina Faso, Sub-Saharan Africa. In this testing, the irrigation depths of the three crops were numerically calculated during the growing stages. Also the irrigation frequencies for the three crops were calculated which are 5 times of

irrigation for both maize and bean and 12 times of irrigation for rice. Rice crop had high water depth and times of irrigation due to its high water requirement. With increased content of soil organic matter to 4 tons, the soil water holding capacity including permanent wilting point, field capacity, saturation and saturated hydraulic conductivity improved for all types of soil in Ouagadougou.

Adamu *et al*. (2012) [1] conducted a study in Dambatta, located in Kano State, Nigeria, to determine the influence of texture and organic matter content on soil water holding capacity in and around Tomas Irrigation Scheme. Threetypes of areas were selected on the basis of land use pattern (I) cultivated land (Jama'a fields) (ii) uncultivated land (Shantake), (iii) Tomas irrigation site. Randomly, 15 soil samples were taken from a soil depth of 0-15 cm, from these three lands. Some common soil tests of these collected soil samples were done on the basis of some soil parameters such as particle size distribution, organic carbon and water holding capacity. The values of the soil organic carbon of the soil samples were calculated and the mean of these values for the Shantake, Tomas irrigation and Jama'a fields were found to be 2.57%, 1.37% and 1.27%, respectively. The soil water holding capacity of the soil samples were found to be 5-25% and the soil texture of the soil samples are observed as sandy and loamy sand. It was observed that the soil organic matter has a higher value in uncultivated field as compared to irrigated fields and continuous cultivation fields. They concluded that the soil organic matter has significant effect on the water holding capacity of soil and the effect was more pronounced when fine textured soil was coupled with appreciable amount of soil organic matter and recommended that high level of soil organic matter should be added to soil for improving the soil water holding capacity.

Vengadaramana *et al*. (2012) [10] conducted a study on Effect of organic fertilizers on the water holding capacity of soil in different terrains of Jaffna peninsula in Sri Lanka.For this purpose; they collected soil samples from 10 different areas of Jaffna peninsula. The main organic fertilizers selected for this study were compost fertilizer cow dung. The results showed that the mean soil water holding capacity of soils from Urumpirai and Ariyali is higher and the mean soil water holding capacity of soils from Iddaikaddu is lower as compared to other soils. A significant difference was observed between the mean soil WHC of the soil treated with organic fertilizers (compost fertilizer and cow dung) and the untreated soils. The soils treated with compost fertilizer and cow dung showed increase in soil water holding capacity. In case of cow dung, it doubly increased the soil WHC. A conclusion of this study was made that increasing the soil organic matter content is the best option for a farmer to increase the soil water holding capacity. Optimum soil water holding capacity in the soil could save time, money and energy spent on irrigation.

T. N. Nath (2014) [8] conducted a study on the determination of the soil texture and total organic matter content and its influences on soil water holding capacity of selected tea growing soils in Sivasagar district, Assam.The thirty soil samples from the depth range of 0-20 cm for ten tea estates were tested and analyzed for soil texture, soil organic matter content and soil water holding capacity. The textures of the soil samples were observed as sandy clay loam and sandy loam and the total soil organic matter content varied from 2.16% to 3.38% with the mean value of 2.71%. The water holding capacity for the soils varied from 50.44 to 59.18% with a mean value of 54.41%. The results showed that the soil samples have medium water holding capacity and soil total organic matter was found to be higher. It was concluded that soil texture and soil organic matter content had influence on water holding capacity of the tea cultivated soil. It was concluded that high concentration of organic matter should be incorporated to the soils for the improvement of the water holding capacity. A significance positive relationship was observed between soil water holding capacity with soil organic matter content and clay, while, a negative relationship was found with sand content and soil water holding capacity.

Effect of polymers on water holding capacity of soil

Geesing *et al*. (2004) [3] studied the influence of sodium polyacrylate on the soil water holding capacity of three different soils and its effects on growth of wheat crop. The effectiveness of sodium polyacrylate to increase soil water retention and to enhance growth of wheat under water deficit condition was evaluated. The water retention capacity (WRC) of three soils amended with the polymer sodium polyacrylate at 0, 1, 3, or 5 g/L of soil was tested.Water retention curves were generated using RETC software (van Genuchten *et al*. 1991). To test the effect of the polymer on plant growth, spring wheat (*Triticum aestivum* L. cv. Thassos) was sown in potting soil containing the polymer at 0, 0.1, 0.5, 1, or 3g/L of soil. The plants were subjected to three water deficit treatments (WDTs) which are: a) no water-deficit stress, b) moderate, c) severe stress, induced by restricting daily watering.Above-ground biomass was harvested from the pots, either before anthesis or at maturity. The plant material was analysed for total N and Na.Water-holding capacity of the soils was considerably increased only when the soil was amended with the polymer at a rate >3g/L. The effect on plant-available water was greater at soil matric potentials up to 1000 h Pa. The biomass and grain yield of plants without water deficit were increased by the polymer amendment, but decreased under severe water deficit stress. The polymer had no significant affect on plant N, grain N or grain Na content.

Vijayalakshmi *et al*. (2012) [11] has studied the effects of polymers on the water holding capacity of soil. They considered the hydro gel polymers for their research experiment. In their experiment, they observed the absorption of water by six polymers - P1, P2, P3, P4, P5 and P6 to study the effect of the polymers on water absorption rate and on soil water holding capacity. The polymers were applied on loamy sand soil. The maximum rates of water absorption by the hydro gel polymers - P1, P2, P3, P4, P5 and P6 were 169.3, 114, 181.1, 154.2, 311.5and 155.8 times their weight respectively. The water holding capacity of soil was carried out in 5 treatments i.e. 0, 0.25, 0.75, 1.25 and 1.75 per cent application of polymer by weight. After the proper analysis of the results, it was found that the application of the polymer to the soil increased the water retention of the soil, increased the soil water holding capacity and decreased the infiltration rate of the soil. The overall conclusion of this research was that polymers have the characteristic to absorb, hold and release water in the soil whenever required by the plants and by the virtue of this, the water is available for plants even at wilting point ultimately increasing the water use efficiency of plants resulting in increasing the yield of plants.

R. L. Flannery and W. J. Busscher (2008) [9] have studied the effect of synthetic polymers on the water holding capacity of the soil. In this experiment, ryegrass, azalea, and impatiens were grown in a greenhouse mix, consisting of 1 part

Spagnum peat moss, 1 part vermiculite and 1 part perlite by volume and three different rates of a synthetic, hydrophilic substance Permabsorb (1.6, 3.2, and 6.4 gm/1) were tested on them. The treatment with the Permabsorb at 6.4 gm/l increased the water holding capacity of the soil significantly. Due to the increased water holding capacity of the soil, the watering frequency of rye-grass is decreased without affecting the yield. Similarly, the yield of azalea is reduced because of decreased aeration in the soil. Impatiens also grew poorly in the treatments of Permabsorb. In this research, overall, it is concluded that the application of the polymers to the soil increase the water holding capacity of the soil.

Effect of biochar amendment on water holding capacity of soil

Basso *et al*. (2012) [2] has studied the potential of biochar for increasing water holding capacity of sandy soils. Hardwood fast pyrolysis biochar was mixed with soil (0%, 3%, and 6% w/w) and placed it into columns in either the bottom 11.4 cm or the top 11.4 cm to simulate deep banding in rows (DBR) and uniform topsoil mixing (UTM) applications, respectively. Then the incubation of four sets of 18 columns was done at 30 °C and 80% relative humidity. In order to have leaching in the columns, 150 ml of 0.001 M calcium chloride solution was added every 7 days. The four sets of columns were harvested after 1, 15, 29, and 91 days respectively. The gravity drained water content increased by 23% with the addition of biochar. Also the bulk density of the control soils increased from 1.41 to 1.45 g cm3 with the increase in incubation time. Whereas the bulk density of biochar-treated soils was up to 9% less than the control soils and remained constant throughout the incubation period. The results also showed that biochar addition to soil did not affect the CEC of the soil. The results of this study suggested that the addition of biochar to sandy loam soil increases the soil water holding capacity and can also increase the availability of water to the plants.

Effect of bentonite amendment on water holding capacity of soil

Junzhen Mi *et al*. (2020) [6] conducted a study in a semi-arid region in northern China to study on the effects of a soil amendment called bentonite on the water holding capacity of soil, plant available water, crop photosynthesis and grain quality parameters for millet (*Setaria italic* (L.) Beauv.) production over a period of 5 years. This experiment include treatments in which six different rates of bentonite amendments (0, 6, 12, 18, 24 and 30 Mg ha^{-1}) are applied only once in 2011. In this experiment, due to the bentonite application (P<0.05), the soil water holding capacity and plant available water increased significantly in the 0–40 cm layer of the soil. In this study, it is concluded that bentonite soil amendment application in the semi-arid regions would result in the beneficial effects on the crop overall growth and also increase the soil water-holding capacity.

Effect of mulching and tillage on water holding capacity of soil

N.H. Abu-Hamdeh (2004) [7] investigated the effect of tillage treatments on soil water holding capacity and on soil physical properties. In this study, bulk density and infiltration rate of the soil is measured from a soil depth of 40cm. Then different tillage treatments were given to the soil and the soil moisture characteristics curves were plotted for different tillage treatments, in order to study the soil WHC. These soil moisture curves were plotted by measuring the soil moisture potential and soil moisture content. For the evaluation of the significance of each parameter and their interactions, ANOVA procedure was used. The results from the data obtained from the experimental plots showed that infiltration rate was strongly affected by tillage treatments in the top soil. Dry bulk density from 0 to 20 cm was affected by tillage treatments and from 20 to 40 cm by axle load. So, a conclusion was drawn in this study that tillage systems have a significant effect on the ability of the soils to hold moisture and the available water capacity.

MaoSheng *et al*. (2010) [4] conducted a study on the effects of different mulching patterns on the water holding capacity of the soil of a non-irrigated apple orchard located in the Weibei Plateau. Different types of mulching like - straw mulching, film mulching, sod mulching practices were done on the soil on the soil of non-irrigated apple orchard and the effect of mulching within 100 cm of soil profile was studied by the measurement of the soil moisture of the soil in the orchard. The results showed that straw mulching enhanced the soil porosity and increased the water-holding capacity of the soil.

Conclusion

In this review study, it has been found that the soil organic matter and the soil texture are the two major factors that have a great effect on the soil water holding capacity. A significant positive relationship was observed between soil water holding capacity with soil organic matter and soil texture. According to this study, high concentration of organic matter should be incorporated to the soils in order to improve its water holding capacity. Increasing the soil organic matter content is the best option for a farmer to increase the soil water holding capacity. In this study, it has been found, that the water holding capacity of the soils was considerably increased when the soil was amended with the polymers like - sodium polyacrylate, hydro gel polymers and synthetic polymers. It is also found that the addition of biochar and bentonite soil amendment increases the soil water holding capacity. Along with this, in this review study, it is also observed that application of straw mulch increases the water holding capacity of soil. Even in some cases it has been found that different tillage systems have a significant effect on the ability of the soils to hold moisture and the available water capacity.

So, from this review study, it can be concluded that the addition of amendments to soil have a great positive effect on water holding capacity of the soil.

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