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Assessment of Super Absorbent Polymer (SAP) on Plant Available Water (PAW) in Dry Lands

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Abstract

One of the ways of overcoming the cost of irrigation is through *in-situ* water harvesting at the plant roots. Super absorbent polymer (SAP) can facilitate water harvesting at the plant roots. This study attempted to assess the effect of SAP on plant available water (PAW) of different soils. In this study, SAP was sequentially added at the rate of 0.2%, 0.3% and 0.5% of the soil weight and its impact assessed in clay, sandy clay and sandy loam soils. The moisture retention characteristics of the original and SAP treated soils were studied using soil water retention curves (SWRC) and results modelled using Gardner model. PAW was estimated from SWRC as the difference between moisture content at 1.5 and 3 bar in all soils. The difference in PAW between original and treated soils was assessed at 5% level of significance. The WRC of all the samples was adequately found to be described by the Gardner model (Coefficient of determination $R^2 \geq 98\%$ and residual standard error (RSE) ≤ 0.04). SWRC changed with increase in SAP percentage in clay, sandy clay and sandy loam soils. Clay had a higher change in water retention then sandy clay and lastly sandy loam. Plant available water content (PAW) in all soils increased. In clay soil it increased with increase in SAP from 0.3291 at zero SAP to 0.6223 at 0.5% SAP. Sandy clay soil increased in PAW from 0.2721 at zero SAP to 0.5335 at 0.5% SAP and Sandy loam soils from 0.1691 at zero SAP to 0.3461 at 0.5% SAP. Hence, from the study SAP can be used to conserve irrigation water in the plant roots and therefore reducing the cost since PAW has been increased.

Keywords

Plant Available Water (PAW), Soil Water Retention Curve (SWRC), Soil, Super Absorbent Polymer (SAP)

1. Introduction

Moisture deficiency to crops in dry lands is high because of the little rainfall experienced and high evaporation capacity. According to the World Health Organization and UNICEF of 2015, they categorised Kenya as a water scarce country. It has only 24% of water as surface and 17% of the land is for potential agriculture experiencing average of (>700 mm) of rainfall and 80% of the land is arid and semi-arid. Water is essential for crop growth.

Soil water is held in different pressure points, which are at saturation or field capacity, wilting point and hygroscopic coefficient [1]. This water can be scarce for crops at different stages of growth hence it is important to advance water-saving agriculture by methods for a coordinated framework that incorporates water-efficient irrigation, agronomic water saving strategies and fitting farming administration [2]. To curb this challenge, different methods of water retention should be introduced. [3] Described that in order to maintain water in the soil for longer periods after an irrigation or rainfall shower, some additional materials such as organic matter, soil conditioners are added into the soil. Super Absorbent Polymer (SAP) is one of the additives used to enhance water retention. It has been observed to be a basic and effective way for conserving water in the soil [2]. SAP can be either natural or synthetic and can absorb water up to 99% or 500 times its own volume [4]. SAP has been used in hygienic measure, especially in dispensable diapers and female napkins where they catch emitted fluids e.g. urine, blood etc. [5]. It is also used in agriculture as soil additives, nutrients reservoir and as water super absorbent [6].

Plant available water (PAW) in the soil is the difference between the volume of water stored when water is at field capacity (FC) at pressures of −300 hpa/30cmpressure/3bar and the volume of water stored when water is at permanent wilting point (PWP) of −15,000 hpa/150cmpressure/15bar. Different soils have different PAW [7]. PAW assists in irrigation scheduling, in that the higher the PAW the higher the irrigation scheduling. Irrigation scheduling aims at achieving an ideal water supply for productivity with soil water content kept close to filed capacity and its main objective is to manage irrigation for the greatest effectiveness [7]. This research tends to use soil water measurement (soil water potential; tensiometer) class of irrigation scheduling. It has the following advantages; can be quite precise, easy to apply in practice, at least water content measures indicate 'how much' water to apply and there are many commercial systems available. It has also some disadvantages, which include soil heterogeneity requiring numerous sensors (frequently costly) or extensive monitoring, choosing position that is illustrative of the root zone is troublesome and sensors do not for the most part measure water status at root surface [7]. SAP is used to either increase or decrease PAW depending on the soil type. SAP has the importance of increasing water holding capacity of soil and according to [8] showed that with SAP moisture content increased from 6.2% to 32.8%, hence PAW.

The approach of the research is to determine the effect of SAP on PAW in a soil water retention characteristic curve (SWRC). The relationship between water in the soil and matric potential is important in characterising the hydraulic properties of soil [9]. This relationship is referred to as Soil Water Retention Curve (SWRC). Modelling of SWRC curve has been done by a number of researchers including: [10]-[18]. Gardner is used in the research for convenience purpose since they all give the same results. SAP effect on the curve, either increasing or reducing the PAW from the control. It is established that residual water amount in soil volume becomes more when blended with super absorbent material [5] [19]. In addition, [20] found out that the use of SAP in the soil increases the water holding capacity and available water and hence water interval increases. This paper tends to determine and discuss the effect SAP on PAW in different soil, if it can assist water conservation in the soil, therefore the effect on PAW.

1.1. Potential of SAP in Improving Plant Available Water

SAP has an ability of storing water up to 500 times its size. To curb the challenge of water scarcity or shortage, SAP should be introduced for water retention. [3]. Plant available water tend to give the best effect of SAP in different types of soils. The concept of PAW as proposed by [21] [22] [23], where they defined it as the difference in soil water content between field capacity (FC) at upper limit and permanent wilting point (PWP) at the lower limit. It indicates the capacity of different soils to store and release water to the roots.

With SAP having high water storage, in this study it also showed that it prevents water trickling to seepage hence increasing PAW in the soil [24].

1.2. Soil Water Retention Characteristics Curve (SWRC) and Plant Available Water (PAW)

Soil water retention characteristics curve is utilized to portray the unsaturated soil conduct and the forces that holds water inside the soil medium. Learning of soil water retention curves (WRCs) is essential for modelling the fluxes of water and solutes in the vadose and subsequently it is important to decide the spatial inconstancy [25]. Since direct field estimations of WRCs are tedious and costly, lab estimations keep on being the most continuous methods for portraying the vadose zone [26]. Soil information retention data are regularly acquired in laboratory for fine soils (<2 mm) utilizing pressure cells, pressure-crop extractors and rotator centrifuge [27]. To obtain the best fit parameters for experimental data of the curve, a non-linear least-square computer program is used. Fitting of SWRC is done with a help of model. There are a number of models that have been proposed and used over years. **Table 1** below shows the models and their parameters.

Soil has the capacity of storing water and providing to crops roots. Quantitative assurance of PAW includes deciding as far as possible (*i.e.* field limit and perpetual withering point), it can be either checked from recorded estimations. The location of PAW inside the soil profile, either shallow and accessible to shallow-established crop species or deep and just available to species with deep

Table 1. SWRC Models with the parameters/Coefficients.

SWRC Model	Model Parameters	Model Reference (Name)
$\theta(h)=\theta_r+(\theta_s-\theta_r)\left[1+(\alpha h)^n\right]^{-m}$	θ_s, θ_r, α, n	Van Genutchen (1980)
$\theta(h)=\theta_r+(\theta_s-\theta_r)\left[1+(\alpha h)^n\right]^{-1}$	θ_s, θ_r, α, n	Gardner (1958)
$\theta(h)=(\theta_s+\theta_r)\mathrm{e}^{-\alpha h}$	θ_s, θ_r, α	Exponential (2007)
$\theta(h)=\theta_s(\alpha h)^{\lambda}$	θ_s, α, λ	Campbell (1974)
$\theta(h)=\theta_r+(\theta_s-\theta_r)(\alpha h)^{\lambda}$	θ_s, θ_r, α, λ	Brooks-Corey (1964)
$\theta(h)=\theta_r+(\theta_s-\theta_r)\left[(1+0.5\alpha h)\mathrm{e}^{0.5\alpha h}\right]^{2/n+2}$	θ_s, θ_r, α, n	Ruso (1988)
$\theta(h)=\theta_r+(\theta_s-\theta_r)\left[1+(\alpha h)\mathrm{e}^{\alpha h}\right]$	θ_s, θ_r, α	Tani (1982)
$\theta(h)=\theta_r+\frac{1}{2}(\theta_s-\theta_r)\mathrm{erfc}\left[\frac{\ln(h/h_m)}{\sigma\sqrt{2}}\right]$	θ_s, θ_r, σ, h_m	Kosugi (1999)
$\theta(h)=\theta_r+\frac{\theta_s-\theta_r}{\left\{\ln\left[2.7183+(\alpha h)^n\right]\right\}^m}$	θ_s, θ_r, α, n, m	Fredlund-Xing (1994)
$\theta(h)=\theta_r+\theta_{s1}\mathrm{e}^{-\alpha_1 h}+\theta_{s2}\mathrm{e}^{-\alpha_2 h}$	θ_{s1}, θ_{s2}, α_1, α_2, θ_r	Biexponential (Omuto, 2009)

establishing root system has been utilized to clarify both the appropriation of existing crops and reaction of vegetation to climate and administration in arid and semi-arid-dry ecosystems and modelling [28].

2. Materials and Methods

2.1. Data Requisition

The data was found with the help of the following materials: SAP-Sodium Polyacrylate, hydrometer and Weighing Balance, Sand Box and Pressure Plate machine. Three different soil samples were classified with the use of hydrometer method. Identification was achieved by use of textural triangle.

2.2. Data Acquisition

Soil textural analysis conveys an idea of the textural make up of soil and it also gives an indication of the physical properties and soil textural class names. Many soil samples from the Kabete soil lab were subjected to test for purpose of textural analysis. The soil samples were passed through a 2 mm sieve before they were subjected for analysis.

Hydrometer method was used for the analysis of the soil samples. Seven 51 g of air dried samples that were first passed through a 2 mm sieve were put in several beakers of 250 mm. The samples were then moistened with distilled water to reduce reaction of hydrogen peroxide. Hydrogen peroxide was then added to help in pre-treatment until no reaction was observed and then 50 ml calgon was added and left for 24 hours. The samples were then put inside seven shaking bottles of 1000 cm^3 and then to a reciprocal shaker which was then shaken for 6 hours. After 6 hours the soil suspension was transferred into glass cylinder and distilled water was added to the one litre mark. The samples were then stirred with the help of a stirrer until all the soils were in suspension.

Hydrometer was then slowly driven into the suspension in the glass cylinders until the hydrometer was seen floating, then the first readings were taken and recorded as (H1) and the temperature of each suspension was taken and recorded as (T1). The second readings were done after 3 hours and recorded as (H2) and (T2) for hydrometer and temperature respectively. The first readings measured the percentage of sand in suspension and the second readings indicated the percentage of clay in suspension. These were repeated in all the samples. Percentages of soil were then calculated as follows in Equation (1)-(3):

$$\text{(a)}\quad \%\text{sand} = 100 - 2\left(\left(\text{H1} - \text{B1}\right) + 0.36\left(\text{T1} - 20\right)\right) \tag{1}$$

$$\text{(b)}\quad \%\text{clay} = 2\left(\left(\text{H2} - \text{B2}\right) + 0.36\left(\text{T2} - 20\right)\right) \tag{2}$$

$$\text{(c)}\quad \%\text{silt} = 100 - \left(\%\text{sand} + \%\text{clay}\right) \tag{3}$$

where: H1 is hydrometer reading one, B1 is hydrometer reading blank, T1 is temperature one, H2 is hydrometer reading two, T2 is temperature reading two and B2 is hydrometer reading blank two.

After the soil percentage was determined, with the help of USDA-SCS [29] textural triangle the soil texture was then classified and three textural classes of soil were identified.

Each class of the three textural classes was then replicated three times. On each replicate, there was a sample without SAP as control and other samples mixed with SAP in proportion of 0.2%, 0.3% and 0.5% in core ring of 100 cm^3 to the weight of the sample in the core rings. After several studies, it was established that you could not go beyond 0.5% of SAP in 100 cm^3 in a core ring. 0%, 0.2%, 0.3% and 0.5% of SAP were chosen for convenience. In each percentage, there were nine core rings for each soil sample and at long last having a total of twenty-seven core rings in all the three soil types with SAP and nine without SAP hence total of thirty-six core rings. 70 g of the samples were used in each core ring. Then all samples were placed inside a sandbox. Sandbox recorded lower values of 0 bar to 2.0 bars hence avoiding errors with logarithmic transformation when it was plotted. Sand box was then filled with distilled water until it was one centimeter below the top of the rings.

The samples were left for two days to attain saturation and hydrostatic equilibrium, then the weight of the samples was taken and recorded as 0 bar. After weighing the core rings, they were returned in the exact spot they were with slight pressing to increase soil sand contact then moved to the next pressure bar of 0.48. The discharge valve was then opened to allow water in the sandbox to be drained until when the hydrostatic equilibrium had been achieved. All the other pressure bars of 1.0, 1.5, 1.8 and 2.0 were taken after every two days and after the hydrostatic equilibrium has been reached *i.e.* no water flows from the sand box to the drainage basin. Figure 1 and Figure 2 shows arrangement of core rings in a sandbox and pF machine.

After this, the samples were transferred to the pressure plate pF machines for higher pF or pressure readings. Pressures of 3, 5, 8, 10 and 15 bars were taken here. Pressures between.1.5 and 3 bars represent the plant available water in the soil. After fifteen bars had been achieved, the soil samples were put in an oven, to be oven dried overnight.

2.3. Data Analysis

Calculations of the soil water retained in each pressure level was done using Equation (4) below

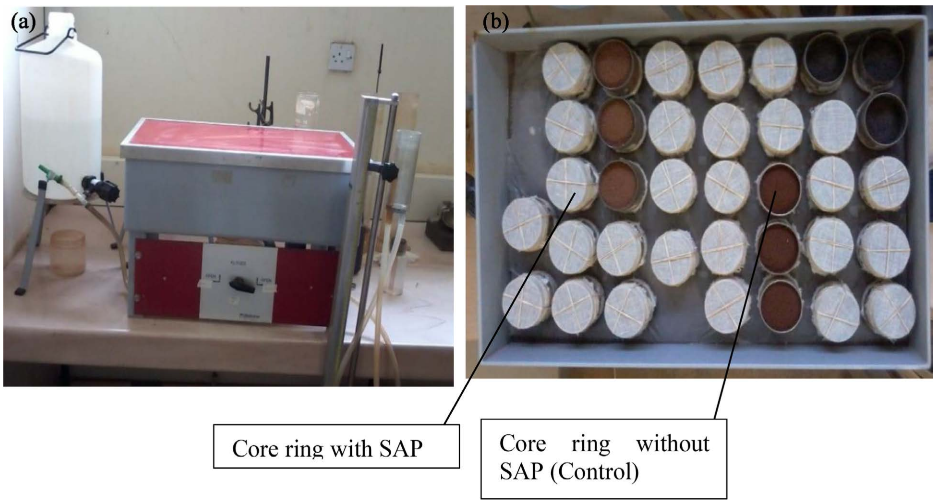

Figure 1. (a) Sand Box; (b) Sand Box with soil samples in Core rings.

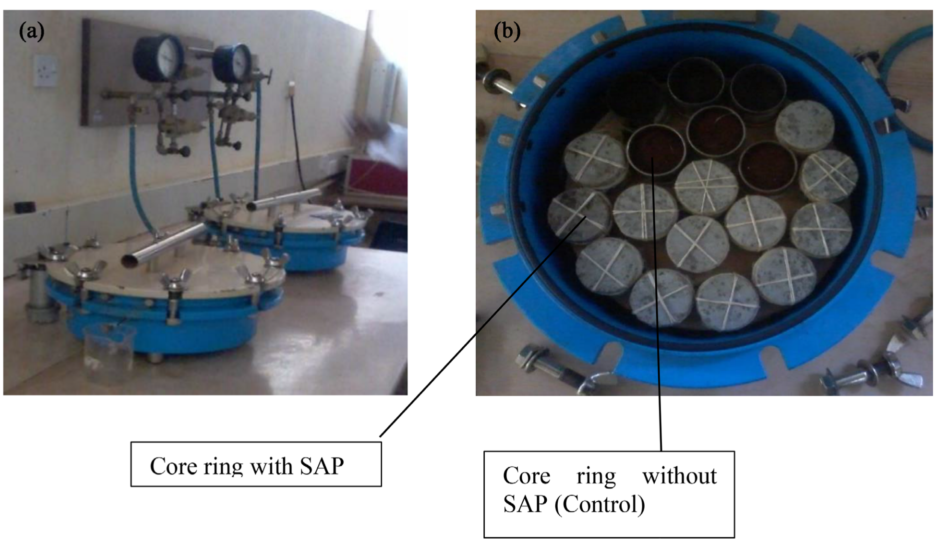

Figure 2. (a) Pressure Plate Machine; (b) Soil Samples in a pressure plate machine.

$$W = \frac{W_w}{W_s} * 100$$

$$W = \frac{\text{Wet.wt} - \text{Dry.wt}}{\text{Dry.wt}} = \frac{\text{Weight loss in drying}}{\text{wt of dried sample}} * 100 \quad (4)$$

SWRC for control was drawn as well as for 0.2%, 0.3% and 0.5% of SAP and analysis done. Plant available water content *i.e.* difference between 1.5bar of pressure and 3 bar of pressure was then determined from the SWRC. Figure 3 below shows the SWRC for clay, sandy clay and sandy loam soils without SAP.

Fitting of SWRC was achieved by use of [13], which is a type of closed form parametric expression for fitting water retention characteristics contained in HydroMe package for convenience purposes since all the other fitting models gives the same results.

The model is described as follows in Equation (5):

$$\theta(h) = \theta_r + (\theta_s - \theta_r)\left[1 + (\alpha h)^n\right]^{-1} \quad (5)$$

where: θ is the volumetric water content, h is the pressure head or the matric potential, θ_s is the saturated water content, θ_r is the residual water content, α and n are the empirical shape parameters.

The effect of SAP was determined in each percentage. PAW in control experiment and soil with SAP at 0.2%, 0.3% and 0.5% and assessed at 5% level of significance determined.

3. Results

3.1. Water Retention Characteristics Model

As explained earlier about the SWRC models and Gardner model used by choice

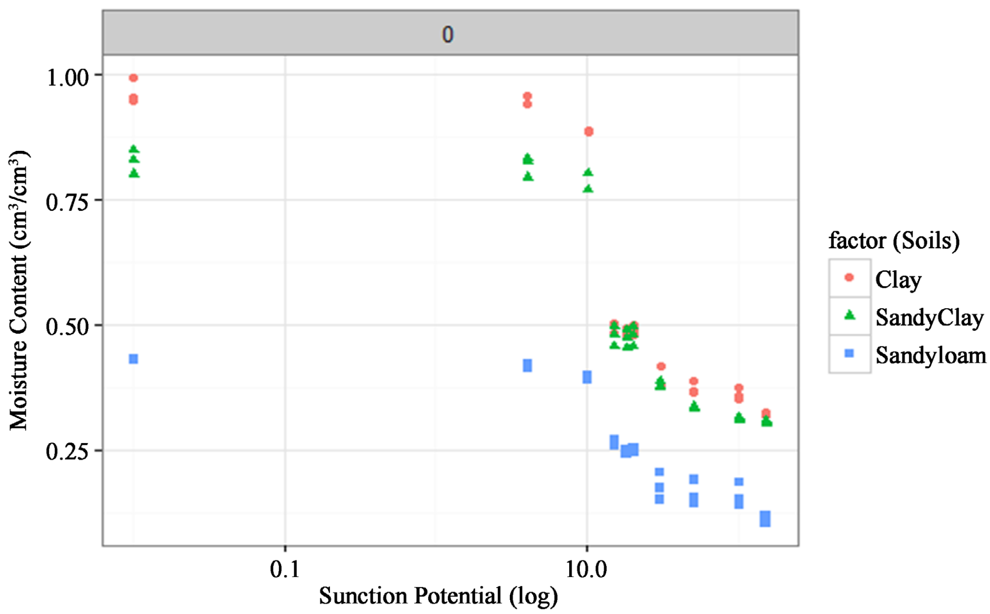

Figure 3. Water retention curves of clay, sandy clay and sandy loam soils.

the following SWRC was produced with help of R-software. Figure 4 show scatter plots for soil water retention curve (SWRC) for clay, sandy clay and sandy loam soils with SAP at 0%, 0.2%, 0.3% and 0.5% to the soil weight.

Clay soil has good water retention as shown in graph with red colour in Figure 4 and is attributed to its fine texture and high-water retention ability [30]. Sandy clay SWRC seen with green colour is the second after clay soil; this is because of presence of clay particles in it. Sandy loam with blue colour in the figure has low ability to retain water in the soil because of the sand texture.

As shown from the figure, in all the soils, there was an increase in volumetric water content with increase in SAP. This is evident and concurs with a research on effects of SAP on the physical and chemical properties of soil following different wetting and drying cycles [8] showed that with SAP moisture content increased from 6.2% to 32.8% and SWR varied according to SAP structure and soil moisture. Further on the study to evaluate SAP rate impact on growth of soybeans [31], it showed that the higher rate of SAP showed high growth rate, high total dry matter and high leaf area index.

Gardner model produced a fitted graph with coefficient of determination (R^2) of greater than 98% and residual standard error (RSE) less than 4% at zero SAP as shown in Figure 5.

Figure 6 shows also the change of SWRC with SAP when soil was mixed with SAP in the proportions of 0.2%, 0.3% and 0.5% to the soil mass sequentially.

It can be seen that there is an increase in volumetric water content with increase in SAP. Since clay has a good retention, with SAP it is also affected twofold. As well, sandy clay experiences the same effect as clay soil with SAP. There is much effect felt in sandy loam soil than in clay and sandy clay as it can be seen from Figure 6. This is due to SAP improving its poor water retention to almost twice its original capacity.

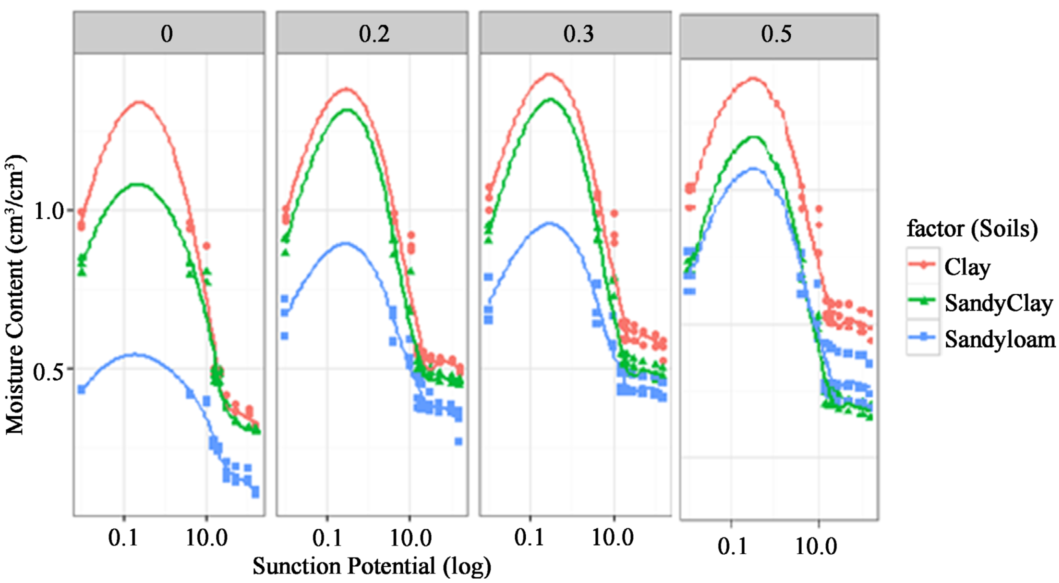

Figure 4. SWRC for all soils (SAP = 0% - 0.5%).

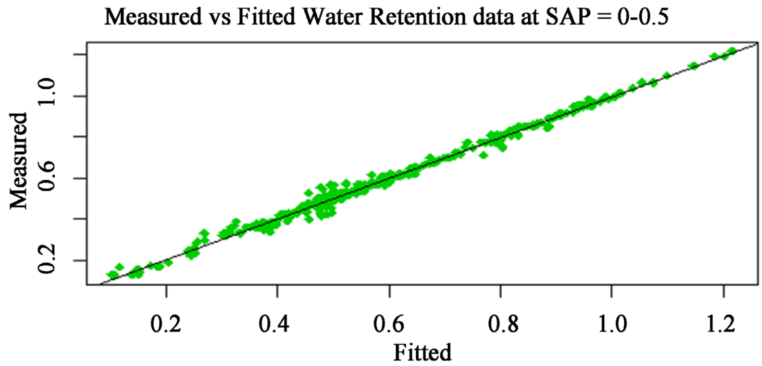

Figure 5. Fitted curve for all soil (SAP = 0% - 0.5%).

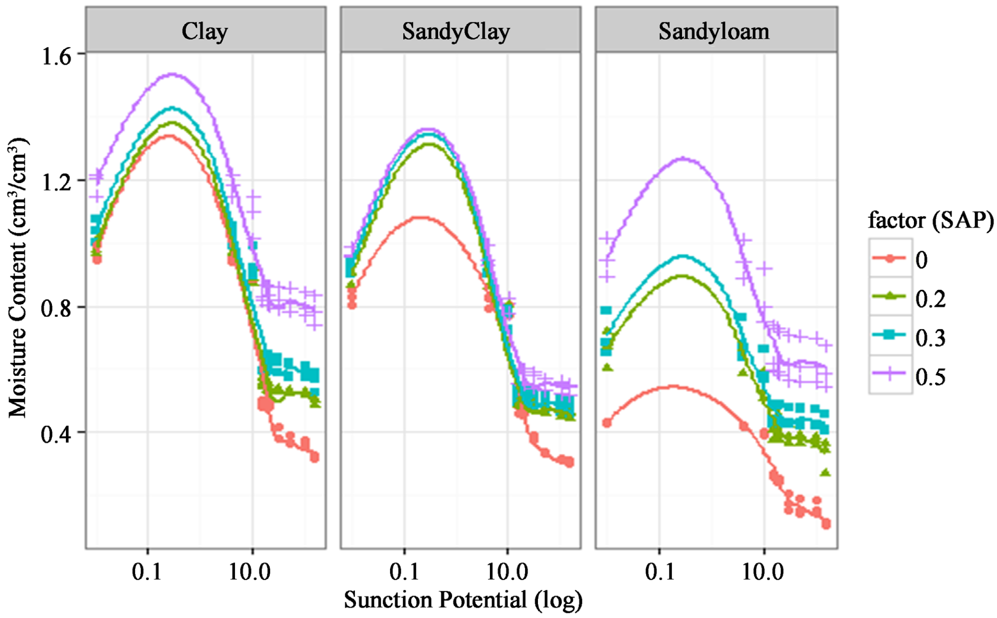

Figure 6. SWRC of Clay, sandy clay and sandy loam soils at SAP = 0% - 0.5%.

At 0.5% of SAP, the soils had the highest PAW as well as the residual water content (θ_r) and saturated water content (θ_s) as shown in Table 1. This shows that an increase in SAP percentage in the soil affects the shape of SWRC and hence its coefficients as discussed.

3.2. Impact of SAP

The impact of SAP on the clay, sandy clay and sandy loam soil SWRC is seen in Table 2 below. The table shows the effect of SAP on SWRC coefficients, which are; PAW, saturated water content (θ_s), residual water content (θ_r), pore index (n) and air entry point (α).

The change of PAW of clay, sand clay and sandy loam soils with SAP, showed increase in PAW with SAP in all the soil types. Clay soil at 0% SAP was 0.3291 then it increased to 0.6223 at 0.5% SAP, sandy loam was 0.2721 at 0% SAP after mixing with SAP at 0.5% it increased to 0.5355 and finally sandy loam soil, had an improvement in PAW from 0.1691 at 0% SAP to 0.3461 at 0.5% SAP. There is

Table 2. PAW of different soils with change in SAP percentages.

Soil Texture	SAP Treatment (%)	Soil WRC coefficients				
		PAW	θ_s	θ_r	α	n
Clay						
	0	0.3291	0.9652	0.3722	8.27E−07	5.4689
	0.2	0.336	0.9787	0.5235	6.51E−11	9.6940
	0.3	0.5053	1.0329	0.6001	3.08E−09	9.2058
	0.5	0.6223	1.186	0.8115	4.34E−10	8.7244
Sandy clay						
	0	0.2721	0.8349	0.3298	3.58E−05	4.2239
	0.2	0.3188	0.8924	0.4735	3.67E−06	7.2297
	0.3	0.4262	0.9219	0.4953	6.4E−09	7.9170
	0.5	0.5355	0.9637	0.5569	2.86E−07	6.5447
Sandy loam						
	0	0.1691	0.4307	0.1420	0.000204	3.1604
	0.2	0.1870	0.6641	0.3550	0.00523	4.6061
	0.3	0.2108	0.7007	0.4397	9.27E−09	8.3381
	0.5	0.3461	0.9914	0.6526	8.46E−06	5.5792

a greater effect in sandy loam. These showed that SAP improves the soil water available for plants hence lengthening irrigation scheduling.

The graphs of PAW against SAP treatment saturated water content (θ_s) against SAP treatment and residual water content (θ_r) against SAP treatment from 0% to 0.5% it further illustrates the effect of SAP. As seen from Table 1, PAW, θ_s and θ_r of sandy loam soil at 0.5% SAP was highly affected than in clay and sandy clay.

Figure 7 shows the PAW effect with SAP from 0% to 0.5%. Clay increased to almost 63% compared to 33% at 0% SAP, sandy clay increased also to 54% compared to 27% at 0% SAP and sandy loam increased more to 34% compared to 16% at 0% SAP. All the soils increased twice its natural PAW at 0.5% SAP, as it can be seen from there gradient line.

Figure 8 below shows the effect of SAP on water saturation. Clay has natural good saturation hence there is no much effect. Sandy clay also experienced little increase with SAP at 0.5% because of the presence of clay texture in it. Sandy loam soil experiences a major effect, twice its original amount with SAP at 0.5% hence shows an improvement in water retention with SAP in sandy soils. The gradient line of sandy loam is higher than that of clay and sandy clay. It depicts that saturation is increasing mostly due to SAP effect.

Figure 9 below shows effect of SAP at 0.5% on residual water content. Clay soil residual water content effect is more from 0.3722 at 0% SAP to 0.8115 at

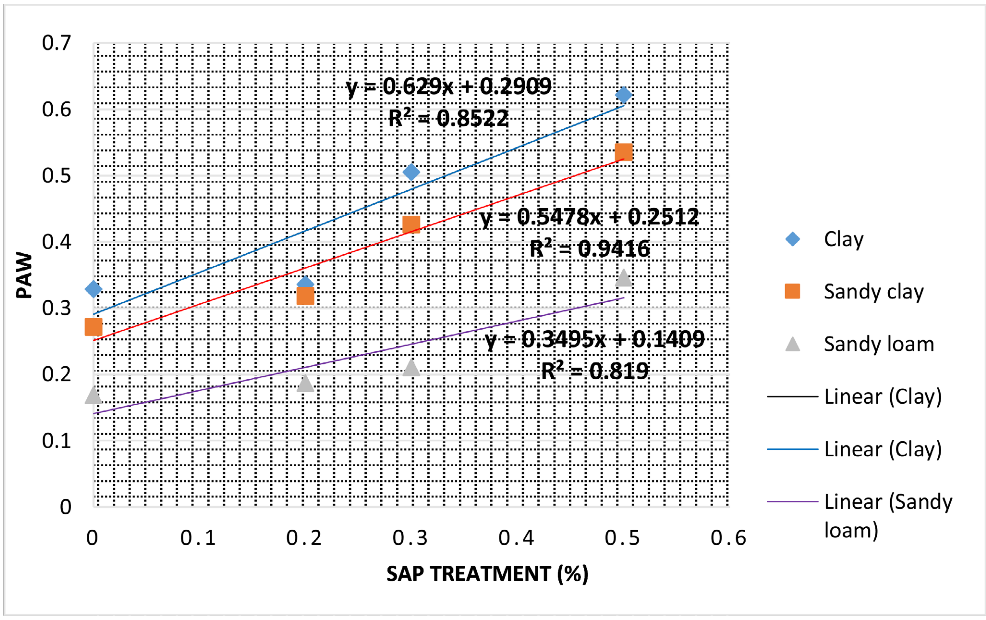

Figure 7. Plant Available Water (PAW) in different SAP percentages.

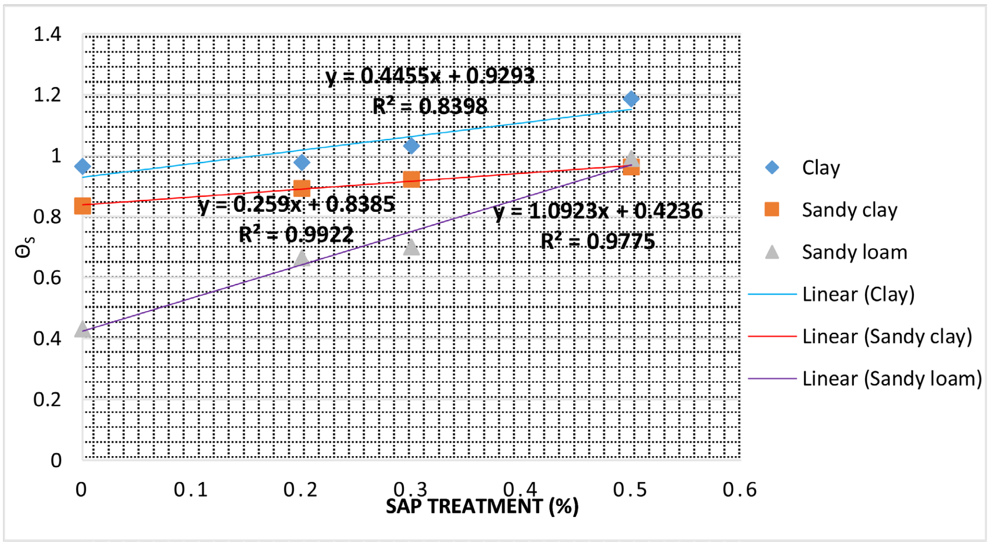

Figure 8. Saturated water content (θ_s) in different SAP percentages.

0.5%. Sandy clay soil did not have much effect from 0.3298 at 0% to 0.5569 at 0.5%. Sandy loam soil experienced most change from 0.1420 at 0% to 0.6526 at 0.5%. The gradient lines and the equations show the change as well. The effect was felt and it shows how SAP can help in improve water in a poorly retained soil such as sand.

The increase in SAP rate brought out a significant increase in the SWRC. A research on the evaluation of hydrogel application on SWRC [15] found out that whichever the type of SAP, an increase in SAP brings out a significant increase in the residual water content (θ_r) and saturated water content (θ_s). This is also evident from this research as seen in **Table 1**. PAW content was determined from the difference in moisture content at 1.5bar pressure, and the moistures

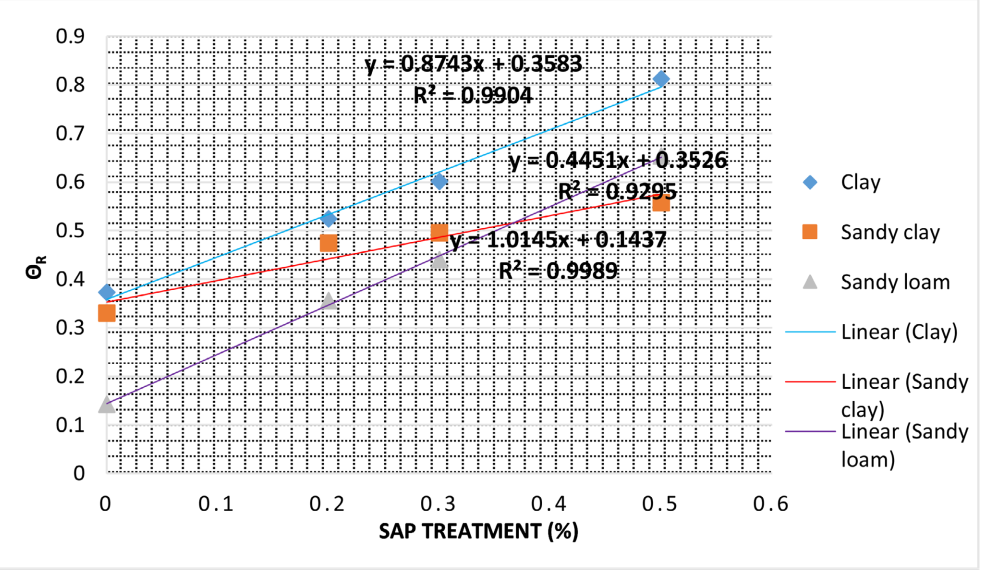

Figure 9. Residual water content (θ_r) in different SAP percentages.

content at 3 bar pressure.

4. Discussion

Water retention in different soils showed that clay has a higher water retention with saturation of 0.9 moisture content, then sandy clay at 0.85 moisture content and the least being sandy loam with moisture content at saturation of 0.43, as it was evident from soil water retention curve (SWRC). These were at the natural state of soil or *in situ* soil.

For the purposes of irrigation in different soils when synthetic substance like super absorbent polymer (SAP) is added into soil, then its effect is identified. The effect of SAP in the soil was realised when soil was mixed with SAP in proportions of 0%, 0.2%, 0.3% and 0.5% to the mass weight of soil. When SAP was added, water retention improved in all the soils. At 0.2% it had a significant increase, then at 0.3% increased further and lastly at 0.5% it had increased the most. This showed water absorption and retention increases with increase in SAP in the soil. Clay soil having a better water retention property, was boosted with the presence of SAP which absorbed to maximum *i.e.* water filling all the pore spaces. Sandy clay's water retention was further improved with increase in SAP percentage. Sandy loam soil water retention was also improved just like clay and sandy clay soils but since it has lower water retention naturally it did not have much increase but a significant change was experienced. This is shown from the SWRC of the soil. The difference can be seen from the control and the ones that have SAP in different percentages.

Plant available water (PAW) is different in different soil types. From the SWRC at the pressures of 1.5 and 3 bar the PAW was found. Clay soil has higher PAW at 0.3291 then sandy clay at 0.2721 and lowest is sandy loam at 0.1691. After mixture with SAP, the PAW increased in all the soils as follows: 0.6223 at

0.5% for clay, 0.5335 at 0.5% for sandy clay and 0.3461 at 0.5% for sandy loam soil. The study showed that the effect of SAP will help in increasing PAW hence it can be used conserve water and cost of irrigation. Also, the residual water content (θ_r) and saturated water content (θ_s) increased with SAP increase. It can be deduced that SAP can be used to help water retention in water stress areas to enhance irrigation purposes.

With the help of Gardner model in fitting the SWRC, a higher fit was found with coefficient of determination (R^2) greater than 98% and residual standard error (RSE) less than 4%. These has been summarised from Table 3 below.

The difference in PAW between original and treated soils was assessed at 5% level of significance to establish whether there was a significant improvement or decline in PAW. The treatment with SAP showed that there was a significant improvement in PAW and other SWRC coefficients such as residual water content (θ_r) and saturated water content (θ_s), *i.e.* Alternative was accepted and hypothesis rejected in that it says there is no difference in PAW in the presence of SAP.

5. Conclusions and Recommendation

5.1. Conclusions

The objective of the research was achieved since the effect of SAP on Plant available water was determined. Clay soil has naturally good water retention than sandy and loamy soils. Due to this it has good PAW.

When a synthetic substance such as SAP is added into the soil, it increases water retention. In this study, clay soil retained water more when SAP was added and increased with the increase in the amount of SAP. Sandy clay soil also increased steadily with SAP but not as much as clay soil. Sandy loam also increased

Table 3. R^2 and RSE of different soils and different SAP percentages.

SAP%	Soil Type	R^2	RSE
0	Clay	0.9768854	0.04780086
	Sandy Clay	0.9684197	0.04629808
	Sandy Loam	0.9702246	0.0247139
0.2	Clay	0.99594765	0.01590498
	Sandy Clay	0.9967698	0.01246004
	Sandy Loam	0.9753878	0.2379756
0.3	Clay	0.991913	0.02143425
	Sandy Clay	0.9964436	0.01349697
	Sandy Loam	0.995481	0.999741305
0.5	Clay	0.9943782	0.01541828
	Sandy Clay	0.9944462	0.01587034
	Sandy Loam	0.9965111	0.01094499

with SAP. The retention increased with increase in the percentage of SAP from 0%, 0.2%, then 0.3% and lastly 0.5%. SAP increases the water retention in all soil types but also depends on its natural state of water retention.

PAW is being increased in all the soils and much experienced in sandy soil. Therefore, SAP can be used to conserve irrigation water and reduce the cost of irrigation since it increases PAW.

5.2. Recommendation

The effect of SAP can be tested in very many soil textures. *In situ* soils should be tested with different types of SAP.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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