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Developing an environmental friendly approach for enhancing water retention with the amendment of water-absorbing polymer and fertilizers

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ABSTRACT

The effect of climate/environmental change has resulted in adverse water stress conditions which necessitates the sustainable approaches for improving the water use efficiency to boost agricultural production in Central Asia. Water-absorbing polymer (WAP) has emerged as one of the amendments for soil water stress management. WAP are chemically cross-linked structure capable of absorbing and storing a large amount of water. The agricultural land has different levels of fertilizers which can influence the performance of WAP because of its sensitivity due to external ionic medium. Therefore, the combined or hybrid use of WAP and organic/ inorganic fertilizers may inhibit the functionality of WAP, which needs to be thoroughly investigated. This study demonstrates the performance of two different WAPs (a commercially WAP (crosslinked potassium polyacrylate) and a laboratory synthesized WAP (crosslinked fly ash-polyacrylate superabsorbent composite)) with varying combinations of fertilizers in silt loam (agrarian soil). The combined use of fertilizers and WAP have improved the water retention properties of soils due to modification in the soil pore volume for both the WAPs. Quantification from water retention properties revealed a significant increase in plant wilting time (PWT) and plant available water content (PAWC) under the combined influence of fertilizers and WAP amended soils, indicating the possibility of high-water availability to plant roots. The study suggests the potential of WAPs as an efficient soil conditioner even in the presence of fertilizer for countering the negative impacts of water stress conditions. WAPs might minimize the requirement for chemical fertilizers, which helps to enhance the climate/ environmental change and agriculture sector in the Central Asian region.

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1. Introduction

Green house gases have an impact on the country's environmental and economic conditions, particularly in Central Asian countries. Climate change caused by humans puts a burden on natural resources such as water availability and air quality. Climate change is one of the most pressing issues of the twenty-first century, impeding the economic progress of Central Asian countries due to extreme weather, insufficient water availability, and poor air quality. Plants and animals struggle to thrive in these conditions. One-tenth of the population in Central Asian countries have lost biodiversity, affecting the global ecology. Central Asian countries have traditionally relied heavily on agriculture. As a result, climate change has increased the likelihood of natural disasters such as heat waves and drought, which may pose a threat to food security in the surrounding regions. In 2021, severe drought swept through Central Asia, causing crop and livestock failure due to a lack of water and forage (Jiang and Zhou, 2023).

A water-absorbing polymer (WAP) is one of the best acceptable alternatives for soil amendment (also known as soil conditioner) to overcome these essential situations. WAP can hold a significant amount of aqueous solution of its own weight. It contributes because of the existence of hydrophilic groups such as amino, hydroxyl groups etc. (Saha et al., 2020; Zainal et al., 2021). Previous research has shown that the WAP is sensitive to salinity and contaminants in the aqueous medium (Souda & Sreejith, 2014; Namazi et al., 2019). The inclusion of monovalent, divalent, and multivalent ions in the swelling media affects WAP performance (Zhu et al. 2015). Ions diminish available water in the WAP network through enhanced crosslink density, resulting in reduction of performance of WAP (Zhang et al., 2014). Mahdavinia et al. 2004 and Saha et al., 2021a reported that pH influences WAP performance, in acidic medium having a greater impact than basic medium. Furthermore, Al-Jabri et al. (2014) reported that water quality influences WAP swelling behaviour. Therefore, before applying WAP in the field, it is critical to understand the performance of WAP under various types of swelling media such as fertilizer and water quality.

Fertilizers, in general, play an important role in agricultural practice for crop productivity. Nutrients and minerals are depleting in agricultural land due to crop species repetition, soil erosion, and other factors. Fertilizers are thus a crucial agricultural element, delivering sufficient nutrients and minerals to improve productivity and growth (Mi et al., 2018). Organic and inorganic fertilizers combined are more productive than inorganic fertilizers alone (Subhan et al., 2017). Sarwar et al., 2008 and Zhou et al, 2017 reported that organic fertilizers provide better performance in terms of plant growth, yield, and soil health compared to inorganic fertilizers. It is hypothesized that the WAP performance has influenced by the fertilizers because inorganic fertilizers are developed through chemical substances that are ionic in nature (Laftah et al., 2011; Kihampa et al., 2013). On the other hand, organic fertilizers are produced from waste products that contain impurities (Schweitzer et al., 2018). Previous research has mostly focused on different soil textures in WAP treated soil to investigate water retention properties (Adjuik et al., 2021; Narjary et al., 2012). Few studies have been conducted to investigate the change in water absorbing capacity of WAP when the water contains dissolved fertilizer salts. (Abd El-Rehim et al., 2006, Bowman et al., 1990; Woodhouse and Johnson, 1991). The soil water characteristics curve is used to assess water retention properties (SWCC). SWCC is described as the relationship between moisture content and matric potential, which helps to facilitate the water requirement, irrigation scheduling, and irrigation frequency for maintaining water status and improving plant productivity (Hung et al., 2021). In addition, the influence of fertilizer only on the water retention capacity of soils is slightly enhanced as reported in the literature Adugna, (2016). Therefore, it is important to comprehend how WAP interacts with the presence of fertilizer in the soil. Hence, knowledge of soil's water retention characteristics (SWCC) is crucial to predicting unsaturated hydraulic properties and designing irrigation schedules and frequency. (Tao et al., 2019; Xie, 2020).

Therefore, it is important to investigate how fertilizers (organic and inorganic) affect the performance of WAP in a locally accessible agrarian soil (silt loam). This study facilitates that the optimum management technique for ongoing water stress conditions with an amendment of WAP. The main objective of this study is to better understand the cumulative influence of WAP and fertilizers on soil hydraulic properties under continued water stress conditions. The impact of two WAPs (commercially WAP (Com-WAP) and in-house developed WAP (FA-WAP)) on the water retention properties of a selected soil (agrarian soil) in the presence of fertilizers (Urea, DAP, and cow manure) were investigated. TEROS 21 and ECH2O 5TM were used to measure matric potential and soil moisture content, respectively during the testing period. SWCC can be used to infer field capacity (FC) and permanent wilting point (PWP) that aid in the quantification of plant available water content (PAWC) and permanent wilting time (PWT) (PWT). According to the findings, both WAP and fertilizers have no harmful effect on the water retention properties of soil.

2. Materials and methodology.

Materials

Soil samples up to 30 cm depth were collected from an agricultural land in Assam, India. After collecting the sample and sieving it through a 4.75 mm sieve, unwanted roots, plastic, and other debris were removed from the soil. The basic properties of soil, such as liquid limit, plastic limit, specific gravity, soil pH, and electrical conductivity, were determined using the methods indicated in the literature (IS 14767 (2000); ASTM D854; ASTM D4318). Table I summarized the basic characterizations of selected soils. The soil was categorized as silt loam by USDA textural classification (USDA, NRCS 2010) based on the above characterization (agrarian soil).

Table I. Basic physical properties of the soil

<table>
<tr><td colspan="2">Physical properties</td><td>Agrarian soil</td></tr>
<tr><td colspan="2">Designation</td><td>AGS</td></tr>
<tr><td colspan="2">Specific gravity (G)</td><td>2.65</td></tr>
<tr><td colspan="2">Hygroscopic water content (%)</td><td>3.8</td></tr>
<tr><td rowspan="6">Grain Size Distribution</td><td>Gravel (> 4.75mm)</td><td>0</td></tr>
<tr><td>Sand (0.075- 4.75 mm)</td><td>13</td></tr>
<tr><td>Silt (0.002 mm -0.075 mm)</td><td>73</td></tr>
<tr><td>Clay (< 0.002mm)</td><td>14</td></tr>
<tr><td>Uniformity coefficient (Cu)</td><td>NA</td></tr>
<tr><td>Coefficient of curvature (Cc)</td><td>NA</td></tr>
<tr><td colspan="2">Liquid limit (%)</td><td>36</td></tr>
<tr><td colspan="2">Plastic limit (%)</td><td>24</td></tr>
<tr><td colspan="2">Plasticity index (PI)</td><td>12</td></tr>
<tr><td colspan="2">Soil pH</td><td>6.3</td></tr>
<tr><td colspan="2">Electrical conductivity (dS/m)</td><td>0.246</td></tr>
<tr><td colspan="2">Cation exchange capacity (meq/100g)</td><td>6</td></tr>
<tr><td colspan="2">Free swell index (%)</td><td>NA</td></tr>
<tr><td colspan="2">USDA textural classification</td><td>Silt loam</td></tr>
</table>

In the current study, two different water-absorbing polymers were selected: one synthesized in the laboratory (in geotechnical engineering, IIT Guwahati, India) for the utilization of industrial waste such as fly ash products, using graft polymerization, and a detailed synthesized process is given in the literature Saha et al. (2020). For comparison to laboratory made WAP, Acura Organic Limited in India supplies an another WAP. In the current study, FA-WAP and Com-WAP are denoted as laboratory synthesid WAP and commercial WAP, respectively. In distilled water, the water absorbency of WAP values were found as 462 g/g and 315 g/g for FA-WAP and Com-WAP, respectively. Several factors influence the WAP's absorption capacity including the backbone material, monomers, initiator, and cross-linkage (Saha et al., 2020). In addition, Com-WAP and FA-WAP have water absorbency in tap water of 375 g/g and 233 g/g, respectively. When compared to distilled water, water absorbency capacity is less in tap water due to the presence of impurities in the solution.

According to Saha et al. (2021), ionic chemicals influence the water absorbency of WAP. And it depends on the valency of the ionic component in the solution, such as monovalent, divalent, or multiple ions. Feng et al. (2014) reported that increasing the valency of ionic compounds decreases water absorbency.

Three different fertilizers were utilized: two inorganics (DAP and Urea) and one organic (Cow manure), which are widely used in agronomy to maintain the needed nutrients in the soil for healthy plant growth. Urea is a white crystalline solid compound that contains 46% nitrogen (NPK rating- 46-0-0). It is a cheap nitrogen fertilizer that is widely available in the market. Furthermore, DAP primarily offers phosphorus nutrition and contains the macronutrients of nitrogen. DAP's most commonly used grade comprises 18% nitrogen and 46% phosphorus (P2O5). It is developed through a controlled chemical reaction between ammonia and phosphoric acid. Cow manure (also known as cow dung) is a waste product produced by animal species such as cows, buffalo, and yak. It's high in minerals like nitrogen, phosphorus, and potassium, as well as organic compounds. It also aids in the improvement of soil microorganisms.

Experimental setup

Total seven combinations of WAPs and fertilizers were planned for this study. The combinations were classified in such a way that the required outcome could be quantified with the fewest treatments. Table II provides a complete overview of various fertilizer and WAP combinations. Control soil (W0) is considered as a reference for comparing treated soil. W1 (Com-WAP) and W4 (FA-WAP) represent the effects of WAP alone, whereas the remaining treatments combines WAP and fertilizers. According to the past research, fertilizer application rates may vary depending on soil texture and crop variety (Chang et al., 2007). Under field conditions, the application rate of inorganic fertilizer varies between 100-150 kg/ha and for organic fertilizer, the application rate varies between 1000-1200 kg/ha (Kumar et al., 2014; Alhasan et al., 2020). In this study, the application rate for inorganic (DAP and Urea) fertilizers is 4% of the considered soil mass, and 10% for organic fertilizers. These fertilizer amendment rates were chosen based on the maximum tolerated limit for the laboratory experiment, and the worst influence of WAP on soil retention qualities may be quantified. According to previous literature, the WAP amendment rate is 0.2% of the soil mass (El-Asmar et al., 2017; Saha et al., 2021a)

Table II. Description of the selected combination of WAPs and fertilizers for this study

Treatments No.	Treatment code	Treatment description
W0	CS	Control soil
W1	SCW	Soil + Com-WAP

W2	SCWO	Soil + Com-WAP + Organic
W3	SCWOUD	Soil + Com-WAP + Organic + Urea + DAP
W4	SFW	Soil + FA-WAP
W5	SFWO	Soil + FA-WAP + Organic
W6	SFWOUD	Soil + FA-WAP + Organic + Urea + DAP

Measurement of water-absorbing capacity

The water absorbency of both WAPs were determined for different concentrations of fertilizers. To measure the WAC of WAP, dry WAP is added to the beaker which is filled with water. The amount of water should be sufficient to reach the WAP in equilibrium. The dry WAP allows water to be absorbed at ambient temperature, and swollen WAP was filtered (through filter paper) under gravity. After draining the extra water, calculate WAC using the formula reported in Witono et al., 2014:

$$Q = {(m_2 - m_1)}\big/{m_1}$$

Where Q is the WAC of the WAP (grams of water per gram of dry WAP) and m1 and m^2 are the weights of dry WAP and swollen WAP, respectively. To maintain the accuracy of Water absorbency of WAP, the solubility of fertilizers were determined: 9% for organic, 57% for DAP, and 97% for Urea which could deduct from the swollen weight of WAP.

Measurement of SWCC

Based on the WAP treatments chosen, dry soil samples were mixed with different WAPs and fertilizers (W0-W6). At the start of the experiment, enough water is added to the soil samples to maintain maximum saturation and soil suction near zero. Sensors were installed in the soil sample for SWCC measurements. In this study, three distinct sensors were used: TERSO21, T5, and 5TM. The TERSO21 (also known as Matric potential senor) (METER Group, Inc., USA) was used to assess the matric suction of amended soil. According to factory calibration, TEROS21 functions accurately in the 9 kPa to 2000 kPa range (Yu et al., 2021). A T5 tensiometer was also utilized to measure the lower range of matric suction between 0 and 100 kPa. The combined usage of TEROS21 and T5 to measure a wide range of suction values for developing SWCC. The ECH2O 5TM senor was utilized to monitor soil water content in this investigation. The presence of WAP and fertilizers may affect the calibration equation of the senor. To reliably assess soil water content, the calibration equation must be developed in the presence of WAP and fertilizers. A detailed explanation of the procedure is not discussed in the present study (Shaikh et al., 2019). Keep in mind that sensors should be installed at the same level and with adequate distance between them to avoid spatial variability and zone of influence, respectively. The adopted methodology for measuring SWCC is presented in detail in Fig. 1.

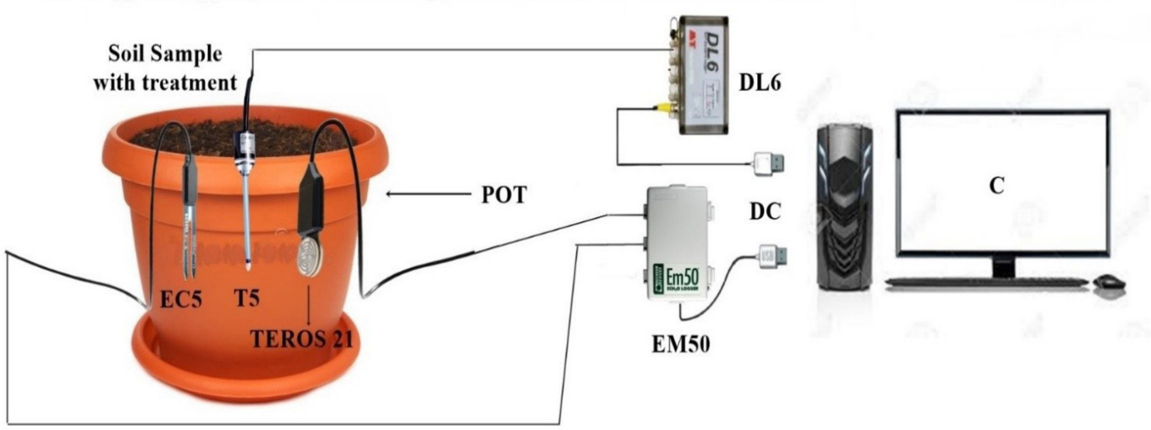
Fitting of SWCCs using vG model

Van Genuchten (1980) is a well-known and widely used SWCC model for determining fitting parameters (avg, nvg, and mvg). These factors are input constraints for comprehending the flow of water through a porous media (Mbonimpa et al., 2006; Likos et al., 2014). This model works with a wide variety of soil types, from fine-grained to coarse-grained. The vG parameters were obtained using the RETC tool, as shown in equations 1 and 2.

$$\theta_\psi = \theta_r + \frac{(\theta_s - \theta_r)}{\left[\left\{1 + (\psi a_{vg})^{n_{vg}}\right\}^{m_{vg}}\right]} \quad (1)$$

$$m_{vg} = 1 - \frac{1}{n_{vg}} \quad (2)$$

Whereas θψ = soil water content at any matric potential, avg = soil parameter that is related to the air entry value (AEV), nvg = rate of water extraction from the soil, mvg = parameter related to the residual water content, θs = saturated water content, θr = residual water content, and ψ = soil matric potential.



T5: Tensiometer; TEROS21: Matric potential sensor; EC5: Moisture content senor; DL6: Data logger for T5; Em50: Data logger for EC5 and TEROS21; DC: Data cable; C: Computer

Figure 1. An adopted methodology for the measurement of soil water retention curve of treated soil

3. Results and discussions

Impact of fertilizer on the water-absorbing capacity of WAP

This section discusses the water absorption capacity of WAP with various fertilizers. The data clearly show that the water-absorbing capacity decreases with an increase in fertilizer content. For both WAPs, the order of WAC decrement is Urea < organic < DAP. FA-WAP has a water absorbency of 315 g/g, 278 g/g, and 265 g/g in urea solutions with the concentration of 0 g/l, 25 g/l, and 50 g/l, respectively. Likewise, water absorbency is found to be 315g/g, 95g/g, and 84 g/g in DAP solution and 315 g/g, 170g/g, and 152 g/g in an organic solution with the concentration of 0 g/l, 25 g/l, and 50 g/l respectively. On the other side, the WAC of Com-WAP is 462 g/g, 430g/g, and 408 g/g in urea solutions with concentration of 0 g/l, 25 g/l, and 50 g/l, respectively. Likewise, 315g/g, 52g/g, and 45 g/g in DAP solution and 315 g/g, 254 g/g, and 230 g/g in an organic solution. Due to the presence of carboxyl groups in WAP, produce an osmotic pressure difference between the aqueous medium and the WAP network in an aqueous solution, results in a repulsive force between the WAP network. The repelling force facilitates the WAP's ability to absorb water molecules (Feng. et al., 2014; Adjuik et al., 2021). WAC reduces when fertilizers (salt and contaminants) are present in the WAP-treated solution (Namazi et al., 2019; Rattan et al., 2022). Due to DAP's ionic nature, which reduces the osmotic pressure difference and, hence the subsequent decrement of water absorbency in DAP solutions. Urea is non-ionic in nature, there is a minor reduction in WAC when compared to DAP and organic fertilizers. Furthermore, organic fertilizer diminishes the WAC of WAP as the concentration of organic fertilizer increases. The reduction in WAC is due to the presence of several ionic -nonionic compounds in fertilizer, which interact with WAP and result in a greater reduction in WAC than Urea (Gupta et al., 2016; Saha et al., 2021).

Influence of fertilizers on SWCC with WAP amended soil

Figure 2 depicts the measured SWCC of agrarian soil with the combined effect of fertilizers and WAP. The figure shows an increase in soil water retention capacity due to the addition of WAP and fertilizers (Rattan et al., 2022). For both WAPs, the improved order of water retention is as follows: control soil < soil + WAP < soil + WAP + organic < soil + WAP + organic + urea + DAP. Water is retained more in the lower suction range due to capillary force, which depends on the pore size distribution and particle size of the soil. On the other hand, higher suction range values retain water due to the water bonding mechanism and specific surface area (SSA). The presence of WAP enhanced the specific surface area, which improved the soil's water retention capacity (Saha et al., 2020). Furthermore, FA-WAP retains more water in the soil matrix than Com WAP. FA-WAP is made of aluminosilicate components, which aid in the advancement of the mechanical properties of the WAP network, such as gel strength and AUL.

As a result, FA-WAP may improve soil water retention more than Com-WAP (Lejcu et al., 2018; Kabiri et al., 2011). Fertilizers also improve soil water retention capacity, which means that soil with both WAP and fertilizers retains more water than soil with WAP only (Chen et al., 2018). It's conceivable that adding fertilizer to the soil would enhance its physical characteristics, such as porosity, bulk density, and aggregate stability, and hence enhance its ability to retain water (Blanco-Canqui et al., 2014; Subhan et al., 2017). Therefore, improving soil water retention aids in maintaining water status under water stress. When adequate water is not available in the soil, stored water from the WAP is used (i.e continued water stress conditions).

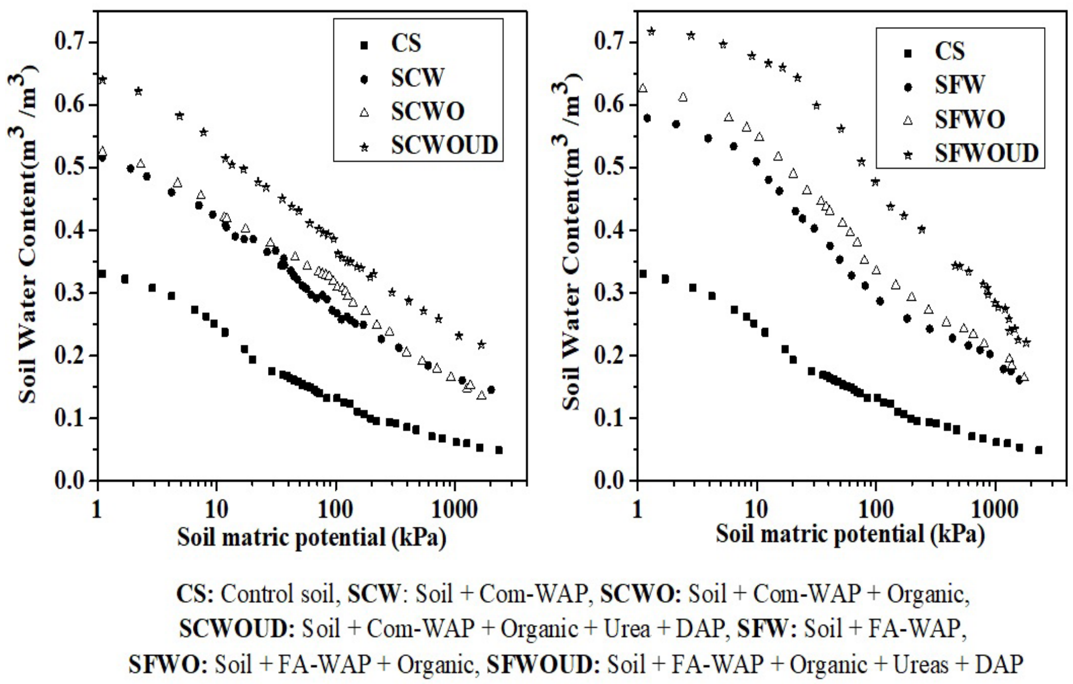


Figure 2. Influence of water-absorbing polymer on soil water characteristics curve in presence of fertilizers.

The vG fitting curve derived for the measured SWCC with WAP and fertilizer treatments. The measured experimental data across the whole suction range is best fit by the vG model. Utilizing least-squares regression, the RETC tool was used to optimise the vG model's fitting parameters. Table III summarize the precise parameters of the vG model. With an addition of WAPs and fertilizers to the soil, the avg parameter (where avg approximates the inverse of air entry value (AEV)) has decreased (Emami & Astaraei, 2012). The suction at which air enters the soil through the biggest pore is defined as AEV. The average values indicate that the control soil has a lower AEV and releases water at a lower suction value. The amendment of WAP and fertilizers fills pores, resulting in a reduction in the diameter of the pore size in the soil matrix (Saha et al., 2020). More pressure is required to extract the water from that pore, resulting in an increase in AEV for the treated soil (WAP and fertilizer amendment) compared to the control soil (Martinez et al., 2019). The vG model facilitates the exact computation of SWCC parameters such as AEV, FC, PWP, and others, improving irrigation scheduling, frequency, and water requirement for plant growth.

Impact on SWC, FC, PWP, and PAWC of WAP amended soil with fertilizers

Saturated water content (SWC), field capacity (FC), permanent wilting point (PWP), and plant available water content can be inferred from SWCC. These parameters are summarized in table IV. Saturated water content defines the maximum amount of water that may be held in it and suction near zero (Lowery et al., 1997). SWC is found to increase due to the addition of WAP and fertilizers (Narjary et al., 2012). With the treatment of W6, the maximum saturated water content was 0.717. (Koupai et al., 2008). In the presence of fertilizers, FA-WAP outperforms Com-WAP in terms of SWC improvement. The trend of water held (saturated water content) by the soil with different treatments is as follows: W0 < W1 < W2 < W4 < W5 < W3 < W6.

Table III. Obtained vG parameters for the present study

vG parameters	CS	SFW	SFWO	SFWOUD	SCW	SCWO	SCWOUD
θr	0.0065	0.1156	0.0362	0.001	0.0014	0.0019	0.0013
θs	0.3454	0.5851	0.6319	0.7162	0.5179	0.4988	0.6526
avg	2.3815	1.0204	0.9944	0.3686	1.7937	0.6636	2.0873
nvg	1.3249	1.3977	1.2773	1.3090	1.2169	1.2548	1.1838
R2	0.9981	0.9975	0.9978	0.9951	0.9942	0.9837	0.9963

Table IV. SWC, FC, PWP, and PAWC of control soil and WAP amended soil with fertilizers

Treatments No.	Treatment	Saturation water content (SWC)	Field capacity (FC)	Permanent wilting point (PWP)	Plant available water content (PAWC)
1	CS	0.331	0.172	0.056	0.116
2	SCW	0.517	0.352	0.155	0.197
3	SCWO	0.525	0.37	0.145	0.225
4	SCWOUD	0.641	0.454	0.221	0.233
5	SFW	0.579	0.395	0.161	0.234
6	SFWO	0.626	0.447	0.173	0.274
7	SFWOUD	0.717	0.594	0.226	0.368

PAWC measures the amount of water incorporated for plant growth. It is the arithmetic difference between the water content at FC and PWP (Vaheddoost et al., 2020). Field capacity (FC) is the quantity of water that remains in the soil after excessing gravitational water has been drained (Cassel and Nielsen, 1986). The precise determination of FC from laboratory experimentation is a challenging task because of variation in pore characteristics and drainage conditions that depend on soil type and compaction of soil sample. Colman (1947) proposed that the FC for all soil types be a matric suction value of 33 kPa corresponding to water content. The water content beyond which plants can no longer draw water from the soil to sustain their life cycle is known as a permanent wilting point. Slatyer (1967) reported the amount of water retained at 1500 kPa in soil conditions (less than 0.2-0.5 m) that water content is considered a permanent wilting point. The results show that WAP-fertilizer-treated soil has higher PAWC than control soil. The increasing order of PAWC as follows: W0 < W1 < W2 < W3 < W4 < W5 < W6. PAWC improved 3.17 times more in W6 ((Soil + FA-WAP + organic + urea + DAP) than in control soil. It is suggested that both WAP and fertilizer aid in the improvement of the PAWC (Chaudhuri et al., 2022; Mahanta et al., 2013). As a result, the addition of WAP to the soil has no negative effect on water storage by WAP in the presence of fertilizers during water stress conditions, which aids in plant growth and survival. These are important agricultural parameters that aid in the design of irrigation scheduling and frequency.

Survival period of soil with the amendment of WAP and fertilizer

The amount of time necessary to reach the permanent wilting point (at a suction value of 1500 kPa) under continuous water stress conditions, i.e., plants cannot obtain water through soil pores at this stage, is known as plant survival time (Abedi-Koupai et al., 2008). The plant wilting time was calculated using the relationship between soil matric potential and time, which is continuously monitored using TEROS21 (refer to suction versus time plot in Fig. 3). The figure shows that WAP-fertilizer-treated soil takes longer to reach to the suction value of 1500 kPa. The increasing order of plant survival time is as follows: W0 < W1 < W2 < W4 < W3 < W5 < W6. The survival time for FA-WAP is increased by 1.45 times and for Com-WAP by 1.39 times (Shahid et al., 2012). Similarly, FA-WAP + fertilizers and Com-WAP + fertilizers were 1.81 and 1.54, respectively. Fertilizers also influence plant survival time, and the combined impact of fertilizers and WAPs is slightly greater than WAP amended soil (Abobatta, 2018). In treatment W6, the maximum wilting time is increased to 1440 hours. These findings indicate that using WAP in the presence of fertilizers can increase water availability and thus extend plant survival period as compared to control soil. This would aid in reducing irrigation scheduling and frequency, resulting in water savings under water stress conditions and improved plant growth. However, the current study was conducted in the laboratory and will need to be thoroughly evaluated in the field.

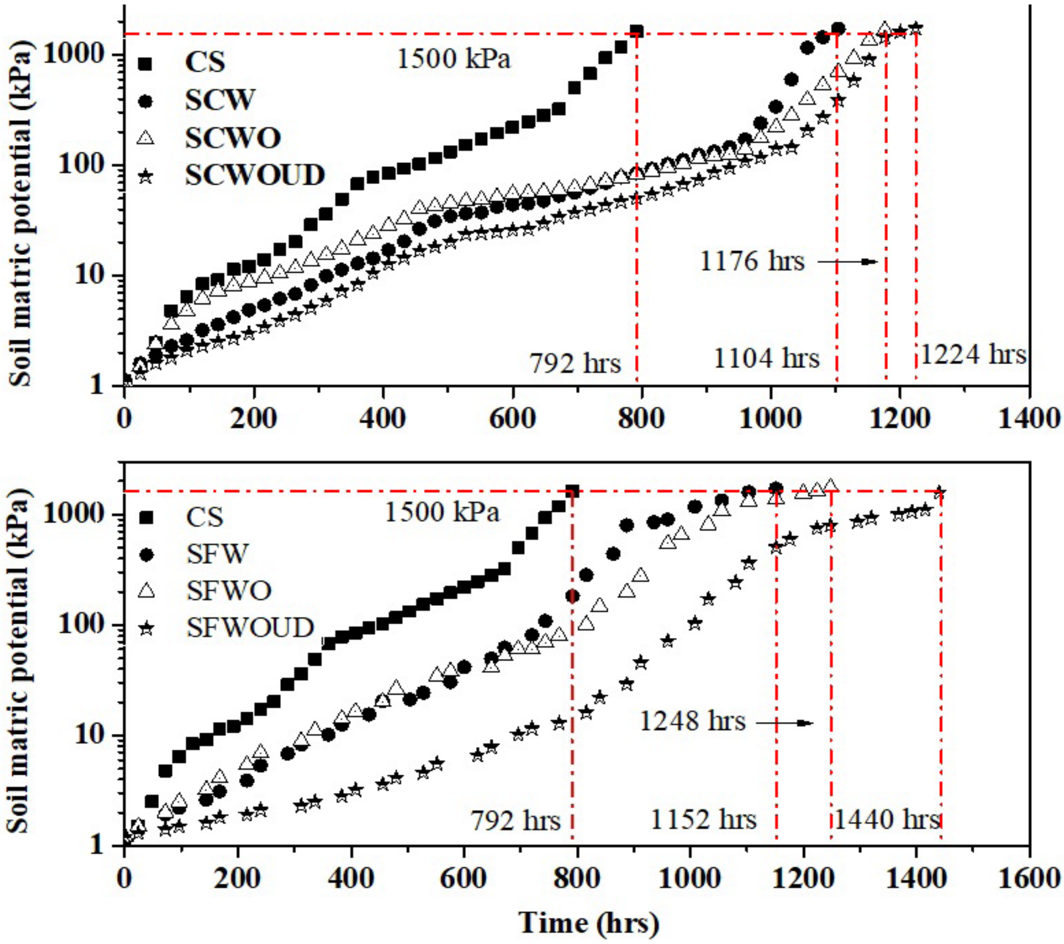


Figure 3. Relationship between suction variation with time for the determination of permanent wilting time (PWT) of WAP amended soil with the presence of fertilizers

Comparison of evaluated parameters with the literature

Table V shows the detailed comparison of evaluated parameters with the literature. The results clearly indicate that the combined WAP and fertilizers amendment has more improvement than those reported in literature. It could be because our findings considered both WAP and fertilizers, whereas the literature only considered the WAP amendment. When all parameters are considered, the average improvement is around 1.2 times greater than the previous findings. It implies that fertilizers, help to improve the water retention characteristics of soil with the presence of WAP rather than hindering WAP performance.

Table V. Comparison of evaluated parameters with previous literature.

Evaluated parameters	Present study (with WAP and fertilizers)	Previous literature (Different amendments)

WAC of WAP with fertilizers	around 50 % decrease	70 % decrease (Saha et al., 2021) (salts)
		65 % decrease (Feng. Et al., 2014) (salts)
Field capacity	increased by 2 times	1.5 times (Akhter et al., 2004) (only WAP)
		1.6 times (Montesano et al., 2015) (only WAP)
Plant-available water content	increased by 2.5 times	1.7 time (Saha et al., 2020) (only WAP)
		3 times (Agaba et al., 2010) (only WAP)
Survival time	increased by 1.75 times	1.5 times (El-Asmar et al., 2017) (only WAP)

4. Conclusion

The interaction between WAP, fertilizers, and soil and its impact on water availability and survival is analysed in this study. The water absorbency capacity of both WAPs was determined using different fertilizer proportions. The findings revealed that DAP has a greater decrease in water absorbency capacity due to its ionic nature. SWCC was measured by consistently recording the water potential and water content with T5, TEROS21, and 5TM sensors for WAP -Fertilizer treated soil. The treated soil has contributed to the pore spaces filled with WAP + fertilizers, which helps to improve soil's water retention properties. The SWC, FC, and PAWC of the W6 treatment ((Soil + FA-WAP + organic + urea + DAP)) were more than twice to control soil. Under water stress conditions, plant survival time increased nearly twofold in the treated soil compared to the control soil. The above results indicate that the presence of fertilizers does not hamper the water retention of WAP amended soil. As a result, WAP amended soil may reduce water demand and irrigation scheduling in arid and semiarid areas especially in Central Asia region Furthermore, this could be an appropriate solution for dealing with critical situations such as water stress (i.e, drought condition). More research is needed to investigate the impact of different amendments, such as plant-available nitrogen, pesticide immobility, and so on, in the presence of WAP on different soil textures in the laboratory and field conditions.

Overall, this study suggests that an environmentally friendly WAPs made can be used to counteract the negative effects of drought conditions. The combined influence of WAP and fertilizer in the soil can help to minimize water demand and reduce irrigation scheduling. This will further help to minimize consumption of water in arid and semiarid regions including Central Asia and hence, promote their agricultural development.

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