

Studying the effect of adding polymers on some physical properties of sandy soil

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Abstract

This study was conducted at the College of Agriculture, Al-Qasim Green University, to investigate the impact of varying levels and depths of polymer addition on certain physical properties of sandy soil. Sandy soil material was collected from the surface layer (0-30cm) in the western region of the Holy Karbala Province. The samples were dried under aerobic conditions, then ground and passed through a 2.0 mm sieve. The sieved soil material was mixed to achieve homogeneity and then divided into three portions. The first portion was combined with polymers at a weight of 2 g/kg on a depth of 10-20 cm. The second portion was mixed with polymers at a weight of 4 g/kg on a depth of 0-30 cm. The third portion was left without mixing, resulting in a total of 27 experimental units. A completely randomized design (CRD) with a pot experiment and three replicates was used in this study. The experimental units were randomly distributed, and the pots were watered. After 72 hours, the bulk density, moisture content, and stability of the soil aggregates in each pot were measured. Results showed a significant decrease in the average bulk density and an increase in the moisture content and stability of sandy soil aggregates with increasing polymer addition rates at 2 and 4 g/kg on a depth of 10–20 and 0-30 cm, respectively; whereas, the non-mixing treatment had no significant effect. These results indicated that increasing the polymer addition level led to a decrease in average bulk density and an increase in moisture content and stability of the soil aggregates.

Keywords: Polymer content, depth of addition, bulk density, moisture content, soil aggregate stability.

Introduction

Sandy soils present a big challenge in the agricultural sector due to their undesirable physical properties. They are characterized by low water and nutrient retention, high drainage rates, poor structure, and instability of soil aggregates. These factors combine to reduce crop yields and increase the consumption of irrigation water and fertilizers. Therefore, searching for soil amendment materials has become crucial. Thus, water-absorbing polymers are among

the most important types of these materials, distinguished by their exceptional ability to absorb and store enormous quantities of water (hundreds of times their dry weight) and gradually release to plant roots when needed.

Mohammed (2016) reported that adding polymers at four different ratios (0, 0.5, 1, and 2 grams of polymer per kilogram of soil) using two methods, the first one was done by mixing the polymer with the soil, and the second one was conducted by

adding polymer at a depth of 15–20 cm from the soil surface. Whereas the result showed a decrease in bulk density values and an increase in porosity, soil aggregation stability, and moisture content compared to the other treatments. Similarly, Al-Omran and Al-Harbi (2021) found that adding polymers to sandy soil resulted in a decrease in bulk density and a significant increase in the soil moisture content.

Abedi-Koupai et al. (2008) found that polymers significantly increased the field capacity of water for the sandy soils, meaning more available moisture for plants. Polymers also contributed to having a better soil structure, which positively impacted root and plant growth under drought stress. Meanwhile, Sojka et al. (2007) Materials and Methods

The soil material was collected from the surface layer (0 - 30) cm of an agricultural field in the western region of the holy Karbala Province. The soil was spread out

demonstrated that polymer addition significantly increased the stability of sandy soils against wind and water erosion, reducing surface crusting and improving seed germination. Saha et al. (2020) indicated that superabsorbent polymers (SAH) effectively modify the physical properties of sandy soils by reducing apparent density, increasing porosity, and raising moisture content, which improved soil structure by increasing the stability of sandy soil aggregates and creating a better root environment. Therefore, the study aimed to evaluate the effectiveness of adding different percentages of polymers at different depths on improving the physical properties (bulk density, moisture content, and soil aggregate stability) of sandy soil.

for the purpose of air drying, and then ground and sieved using a 2 mm sieve. Samples were placed in tightly sealed plastic containers for the purpose of conducting some physical analyses on them, as listed in Table 1 below.

Table 1: General characteristics of the study soil

| Parameters | Value | Unit of Measurement |
|------------------------------|-------|---------------------|
| Soil volume analysis | | |
| Sand | 87.00 | % |
| Silkenage | 8.00 | % |
| Clay | 5.00 | % |
| Bulk Density | 1.55 | Mg ^{- 3} |
| Particle Density | 2.65 | Mg ^{- 3} |
| texture | - | Sandy |
| Moisture Content at 33 kPa | 15 | % |
| Moisture Content at 1500 kPa | 5 | % |
| Soil Agglomeration Stability | 18 | % |
| Electrical Conductivity | 1.6 | ds.m ⁻¹ |
| Soil Reaction (Ph) | 7.8 | - |
| Organic Matter | 0.05 | % |

Preliminary analyses of the general properties of the study soil:

1. Bulk density was estimated using the cylinder method for undisturbed soil samples, as described by Blacke and Hartge (1986).
2. Particle density was estimated using the density bottle method, as described by Blacke and Hartge (1986).
3. Particle size distribution was estimated using the pipette method, as described by Blake et al. (1965).
4. Moisture content at field capacity and permanent wilting point was estimated at 33 and 1500 kPa using a pressure cooker, as described by Klute et al. (1986).
5. Organic matter content was estimated using the wet digestion method described by Black (1982).

Statistical analysis

The data for the studied traits were analyzed using the SPSS program, and the comparison was made based on the value of the least significant difference (LSD) at a probability level of 0.05.

Results and discussion

1 - The effect of level and depth of polymer addition on bulk density values (Mg m^{-3})

Table 2 shows significant differences in the mean bulk density values under the influence of polymer levels. The highest value of 1.65 Mg m^{-3} was found at the P0 addition level, while the lowest value of 1.52 Mg m^{-3} was found at the P2 addition level. This result indicates that with

6. Electrical conductivity (ECc) and soil reactivity PH were estimated in the saturated paste extract using an EC meter, as described by Page et al. (1982).

The sieved soil was divided into three parts using a 2 mm sieve. The first part was mixed with polymers at a rate of 2 g/kg to a depth of 10–20 cm. The second part was mixed at a rate of 4 g/kg on a depth of 0–30 cm, and the third part was left unmixed. Two factors were used in the experiment: the polymer ratio factor at three levels and the mixing depth factor at three depths. A completely randomized design (CRD) was used, and the treatments were randomly planted with three replicates with 27 experimental units. The soil in the pots was then irrigated to 50% of field capacity, and laboratory tests were performed after 72 hours.

increasing polymer addition levels, the bulk density decreases. The reason for this decrease is attributed to the ability of polymer particles to expand after absorbing water, which pushes the soil particles apart and increases the total soil volume, which then decreases the density. This result is consistent with the findings of Wallace & Terry (2019), who indicated that polymer addition improves soil structure by binding the primary soil particles together, which leads to increasing the total pore volume and decreasing bulk density. Similarly, Chen et al. (2021) demonstrated that polymer addition increases the stability of soil aggregates and reduces particle adhesion, thereby reducing bulk density and opening up soil pores. Al-Saadi (2022) also noted a significant decrease in the apparent density values of sandy soil, where it decreased

from 1.65 Mg m⁻³ to 1.35 Mg m⁻³ compared to untreated soil.

Table 2 shows the significant effect of mixing depth on the average bulk density values. Where the highest and lowest values for this characteristic were found to be 1.60 and 1.58 Mg·m⁻³ under the influence of mixing depths D2 and D3, respectively. The above result indicates that mixing at depth D2 achieved better polymer distribution and greater improvement in soil structure. This result is consistent with the findings of Sadeghi et al. (2021), who showed that polymer activity achieved its peaks when mixed in the top layer (10–20 cm), where root activity and aeration are high.

Table (2): Effect of the level and depth of polymer addition on bulk density values (Mg m⁻³) at the end of the experiment.

| weight of polymers (P) g/kg | Mixing depth (cm) D | | | Means |
|--------------------------------|--------------------------------------|--------------------|-------------------|-----------------|
| | Without mixing (D1) | (10-20 cm) (D2) | (0-30 cm) (D3) | |
| P0 (0g) | 1.65 | 1.64 | 1.66 | 1.65 |
| P1 (2g) | 1.63 | 1.58 | 1.60 | 1.60 |
| P2 (4g) | 1.50 | 1.53 | 1.55 | 1.52 |
| Means L.S.D (0.05) | 1.59 | 1.58 | 1.60 | L.S.D (P)=0.007 |
| | L.S.D (D)=0.004 ; L.S.D (P×D) = 0.03 | | | |

2 - The effect of the level and depth of polymer addition on the moisture content values of sandy soil:

The results shown in Table 3 indicate significant differences between the mean values of soil moisture content under the influence of polymer levels. The highest value of 14.20 was found at the P2 addition level, and the lowest value of 5.20 was found at the P0 addition level. This result suggests that increasing the polymer addition level leads to an increase in soil moisture content. This is attributed to the polymers' ability to absorb and store hundreds of times their own volume of water. This finding is consistent with the

The results of the two-way interaction between polymer addition levels (P) and depth levels (D) in the table above showed significant effects on the mean bulk density values. The highest and lowest mean bulk density values for the soil were found to be 1.66 and 1.53 Mg·m⁻³ under the influence of the P0D3 and P2D2 treatments, respectively. This result indicates that with increasing addition levels and decreasing depth, bulk density decreases, while with decreasing addition levels and increasing depth, the value of this characteristic increases.

results obtained by Wallach et al. (2005), who demonstrated the role of polymers in increasing soil water retention capacity, particularly in highly porous sandy soils. A study by Khalaf et al. (2022) also showed that adding a superabsorbent polymer to sandy soil improves its water retention capacity. Furthermore, Al-Marzouki (2021) demonstrated that after 72 hours of polyacrylamide application, soil moisture increased from 12% to 28%, and irrigation consumption decreased by 37% compared to untreated soil.

The results in Table 3 showed that the application depths D3 and D2 resulted in the highest moisture retention compared to

depth D1, which experiences rapid water loss through evaporation and does not affect the lower layers. Mixing at a depth of (10-20) cm distributes the polymers in the root zone, thus improving soil moisture retention. This result is consistent with the findings of (Bhardwaj et al., 2007).

The interaction results between the addition levels and mixing depths showed significant differences between the values of moisture content for the interaction coefficients. The highest value for the characteristic under

Table (3): Effect of the level and depth of polymer addition on the moisture content values (%) of sandy soil at the end of the experiment.

| weight of polymers (P) g/kg | Mixing depth (cm) D | | | Means |
|--------------------------------|------------------------------------|-----------------|----------------|----------------|
| | Without mixing (D1) | (10-20 cm) (D2) | (0-30 cm) (D3) | |
| P0 (0g) | 5.20 | 5.10 | 5.30 | 5.20 |
| P1 (2g) | 5.80 | 12.50 | 15.10 | 11.13 |
| P2 (4g) | 6.50 | 18.90 | 17.20 | 14.20 |
| Means L.S.D (0.05) | 5.83 | 12.16 | 12.53 | L.S.D (P)= 2.0 |
| | L.S.D (D)= 2.0 ; L.S.D (P×D) = 3.4 | | | |

3 - The effect of the level and depth of polymer addition on the stability of sandy soil aggregates at the end of the experiment.

The results shown in Table 4 indicate significant differences between the mean stability values of soil aggregates under the influence of polymer levels. The highest value of 32.80 % was found at the P2 addition level, while the lowest value of 15.80 % was found at the P0 addition level. This result indicates that with increasing polymer addition levels, soil aggregate stability increases. This is due to the role of polymers in binding soil particles and forming aggregates. This result is consistent with what was obtained by Seybold, C. A. (2019). He indicated that when superabsorbent polymers such as polyacrylamide (PAM) are mixed with soil,

study (18.9) and the lowest value (5.2) were found at the addition levels P2D2 and P0D0, respectively. This result showed that with increasing the addition level and increasing the depth, the soil moisture content increases due to the ability of polymers to retain water. This result was consistent with what was obtained by Shainberg et al. (2001), who indicated that superabsorbent polymers (SAPs) increase the soil's ability to retain water, especially in sandy soils with high porosity and low ability to retain moisture.

the long elastic polymer chains begin to wrap around the sand grains. These chains form "bridges" that connect several grains, creating a three-dimensional network structure. This network holds the grains in place even under the influence of external forces such as wind, raindrops, or irrigation. Meanwhile, Ahmed Al-Saadi (2022) found that after 30 minutes of adding polymers to the soil, the stability of the aggregates increased to 78-88% compared to untreated soil, where the percentage was 22-28%.

Sojka et al. (2007) found that the polymers used (especially anionic polyacrylamide) carry a negative charge, while the surfaces of some clay minerals and iron and aluminum oxides in the soil carry positive charges at specific locations. This leads to an electrostatic attraction between the

(negative) polymer and the positive charge locations on the granules, which enhances the bonding strength and stabilizes the aggregates further.

Table 4 shows the significant effect of depth levels on the average stability values of soil aggregates. Depth D1 recorded the lowest value of 16.20 % due to the absence of polymer addition at this depth. In contrast, depth D2 recorded a value of 28.63% . At this depth, polymer distribution is better distributed in the root zone, with sufficient moisture present for soil aggregate formation. At depth D3, the stability value of soil aggregates was 30.26 % . At this depth, the polymer concentration decreases because the soil volume is larger, which reduces the polymer effectiveness compared to D2 at the highest concentration (P2). This result is consistent with Sebastian et al. (2022), who found that mixing in a 10–20 cm layer was optimal for improving the physical properties of sandy soils.

The results of the two-way interaction between polymer levels (P) and depth levels

(D) in the table above show significant effects on the mean soil compaction stability values. The highest and lowest mean soil compaction stability values were found to be 41.70% and 15.50 %, respectively, under the influence of the P2D2 and P0D1 treatments. This result indicates that with increasing polymer addition levels and depth, soil compaction stability increases, and vice versa. This demonstrates that with increasing polymer addition levels, soil compaction stability increases at any of the study depths. However, the magnitude of this increase in the studied characteristic decreases at depth D3 because the soil volume at this depth is greater, resulting in a lower polymer concentration compared to depth D2, where the concentration is higher and the soil volume is lower. This result is consistent with the findings of Ahmed (2021), who recommended using 4 g/kg of mixed polymer in the root zone to improve soil structure stability and soil compaction resistance.

Table 4: Effect of the level and depth of polymer addition on the stability (%) of sandy soil aggregates at the end of the experiment.

| weight of polymers (P) g/kg | Mixing depth (cm) D | | | Means |
|--------------------------------|--------------------------------------|--------------------|-------------------|----------------|
| | Without mixing (D1) | (10-20 cm) (D2) | (0-30 cm) (D3) | |
| P0 (0g) | 15.50 | 15.80 | 16.10 | 15.80 |
| P1 (2g) | 16.80 | 28.40 | 35.20 | 26.80 |
| P2 (4g) | 17.20 | 41.70 | 39.50 | 32.80 |
| Means L.S.D (0.05) | 16.50 | 28.63 | 30.26 | L.S.D (P)=2.21 |
| | L.S.D (D)= 2.21 ; L.S.D (P×D) = 3.84 | | | |

Conclusion

This study concluded that the addition of polymers has a significant positive effect on improving the physical properties of sandy soil. Whereas the effectiveness of the polymer depends crucially on its application method. Improving the stability of the soil aggregates indirectly contributes to improved aeration and reduced water and wind erosion. Total mixing (0–30 cm) or mixing within the root zone (10–20 cm) was the most effective. Finally, adding polymer at a weight of 4 g/kg was the most effective in reducing bulk density, while the optimal mixing depth for the polymer is 10–20 cm to achieve the greatest improvement in structure.

References

1. Ahmed Abdullah Al-Saadi (2022). The effect of polychlorinated materials on the properties of sandy soils in arid regions. *Journal of Geotechnical Engineering*, 7(2), 45–60
2. Ahmed, M., & Dib, K. (2021). The effect of superabsorbent polymers on soil compaction resistance and structural stability. *Journal of Arid Land Agriculture*, 15(3), 45-52
3. Abedi-Koupai, J., Sohrab, F., & Swarbrick, G. (2008). Evaluation of hydrogel application on soil water retention and plant growth under drought stress. *Journal of Plant Nutrition*, 31(2), 317-331
4. Al-Marzouki, A. (2021). Evaluation of the efficiency of different types of superabsorbent polymers in improving the properties of sandy soils and water conservation. *International Journal of Agricultural Engineering*, 29(4), 112–130
5. Al-Omran, A. M., & Al-Harbi, A. R. (2021). Impact of soil conditioners on water conservation and plant growth in sandy soils: A review. *Saudi Journal of Biological Sciences*, 28(1), 1-10
6. Bhardwaj A; K ; Sheinberg .D, Goisteinl .D,N Warrington Water Retention And Hydraulic Conductivity Of Cross-Link Poly Acryl Amid In Sandy Soils, *Soil Sci Soc Am N 71*, 2007:406-412
7. Black, C. A., Evans, D. D., White, J. L., Ensminger, L. E., & Clark, F. E. (Eds.). (1965). *Methods of Soil Analysis, Part 1. Agronomy Monograph No. 9.* American Society of Agronomy
8. Blake, G. R., & Hartge, K. H. (1986). Particle Density. In A. Klute (Ed.), *Methods of Soil Analysis, Part 1: Physical and Mineralogical Methods* (2nd ed., pp. 363-381). SSSA
9. Chen, L., et al. (2021). Effects of soil conditioners on physical properties and crop growth in compacted soils. *Soil & Tillage Research*, 205, 104768
10. Khalaf. (2022). The effect of adding a potassium-containing superabsorbent polymer to sandy soils. PhD dissertation. University of Baghdad
11. Sebastian. (2022). The effect of different soil incorporation depths in sandy soils in drip irrigation systems on the physical properties of the soil and potato yield. PhD dissertation. College of Agriculture. University of Kirkuk
12. Sadeghi, S., et al. (2021). Optimizing depth of soil amendment incorporation for maximum root growth. *Agricultural Water Management*, 247, 106734
13. Saha, A., Sekharan, S., & Manna, U. (2020). Superabsorbent hydrogel (SAH) as a soil amendment for drought management: A review. *Soil and Tillage Research*, 204, 104736
14. Seybold, C. A., Ferguson, R., Wysocki, D., Bailey, S., Anderson, J., Nester, B., ... & Thomas, P. (2019). Application of mid- infrared spectroscopy in soil survey. *Soil Science Society of America Journal*, 83(6), 1746-1759
15. Shainberg, I., et al. (2001). Effect of polyelectrolytes on the electrophoretic mobility of bacteria and the stability of their suspensions. [Journal Title Missing]