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EFFECTIVE SOIL ADDITIVES FOR IMPROVED SOIL WATER RETENTION

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The study was conducted during 2010 at Pir Mehr Ali Shah, Arid Agriculture University Rawalpindi, Pakistan, to screen soil additives with improved water retention. Different soil additives i.e. Qemisoyl, gypsum, compost and farm yard manure (FYM) were evaluated to quantify plant available water under controlled conditions. The samples of clay loam soil were subjected to various pressure levels (33 to 1500 kpa) to develop soil moisture characteristic curves. The results revealed that highest soil moisture content at field capacity (0.284 m^3 m^{-3}), permanent wilting point (0.146 m^3 m^{-3}) and plant available water content (0.138 m^3 m^{-3}) was recorded with the application of Qemisoyl @ 15 kg ha^{-1} as compared to control (0.251, 0.128 and 0.123 m^3 m^{-3}, respectively). Generally, the combined use of various soil additives was equivalent to their sole applications. The results indicated that soil moisture retention can be enhanced with the application of soil additives especially Qemisoyl @ 15 kg ha^{-1} that gave about 12% higher moisture retention than control to achieve higher levels of crop production in drought-hit areas to ensure food security. Further comprehensive field studies based on results of present laboratory study may help develop useful water harvesting/capturing interventions at the farm scale.
Keywords: Qemisoyl, gypsum, compost, field capacity, permanent wilting point

INTRODUCTION

Crops in rainfed ecology suffer from soil moisture stress at critical growth stages, hence yield per unit area are low (Blum, 2009). This leads to food insecurity and poor economic conditions of the farmers. Rainfed agriculture is practiced on 25% of the cultivated areas (20.43 m. ha.) of Pakistan (Shahbaz and Hanjra, 2009). The region faces challenges of water scarcity, low soil fertility, and erosion hazards. The rainfall distribution is highly skewed in favour of summer with torrential monsoon showers followed by prolonged early season drought to following winter crops (Nizami *et al.,* 2004). Crop yield could be improved under water-limited environments by capturing every drop of rainfall to meet the goal of more crop per drop. This could be achieved by adopting specific crop and soil management practices such as soil additives including hydrogel, FYM, compost and gypsum through higher soil water retention (Kijne *et al.,* 2003).

The soil additives were found to favorably modify soil water relationships especially water retention and transmission (Chaudhry, 1992) through improving soil aggregation (EL-Hady *et al*., 2006; Sharma, 2004), nutrient retention, aeration, water infiltration and soil water holding capacity (Deksissa *et al.,* 2008). Thus decreasing runoff and erosion (Yu *et al.,* 2003; Rashid *et al.,* 2008) and leading to improved crop production in rainfed environments (Sharif *et al.,* 2004). Hydrogel (Qemisoyl) is long lasting, water absorbent with ability to absorb and retain a large amount of water along with nutrients for uptake of crops. One gram of Qemisoyl has the ability to absorb up to 500 ml of water. This polymer applied once remained functional for 4-7 years in the soil (Monning, 2005).

Crop yield based data on use of green manures and gypsum for increasing crop yields in rainfed ecology of Pakistan is available (Rashid *et al.,* 2008); however, comprehensive studies using combinations of additives such as hydrogel, compost, gypsum and farm yard manure have not been conducted. We hypothesize that combined effect of these additives will be different than their individual use. Therefore, the present study was conducted with the objective to quantify the effect of different soil additives to improve the available water capacity of the soil.

MATERIAL AND METHODS

A comprehensive laboratory study was conducted in the Department of Soil Science & Soil Water Conservation, PMAS-Arid Agriculture University Rawalpindi, Pakistan. Bulk of loamy soil taken from the university research farm was air dried, ground and passed through 2 mm sieve. Then following treatments of different additives were applied to a measured quantity of soil with three replications: i) Control (without any additive), ii) Qemisoyl @ 15 kg ha^{-1}, iii) Farm

Yard Manure (FYM) @ 25 Mg ha^{-1}, iv) Compost @ 0.75 Mg ha^{-1}, v) Gypsum @ 2.5 Mg ha^{-1}, vi) Qemisoyl + FYM, vii) Qemisoyl + Compost, viii) Qemisoyl + Gypsum, ix) FYM + Compost, x) FYM + Gypsum, xi) Compost + Gypsum, xii) Qemisoyl + FYM + Compost, xiii) Qemisoyl + FYM + Gypsum, xiv) Qemisoyl + Compost + Gypsum, xv) FYM + Compost + Gypsum, xvi) Qemisoyl + FYM + Compost + Gypsum. The application rates for various combinations of soil additives (Qemisoyl, FYM, Compost and Gypsum) were same as given in earlier treatments (i to v). Hence, soil additives have been mentioned without their dose hereafter.

The water absorption and retention properties of different treatments were measured using Pressure Membrane Apparatus (Model 1500F1, Soil moisture Equipment Corp. USA). Pressure plates along with soil samples were saturated in water overnight and then each soil sample was applied with pressures of 0.33, 1, 3, 7 and 15 bars for 48 hours in pressure membrane apparatus. Afterwards the soil samples were removed and moisture contents of the samples were measured gravimetrically. RETC-Fit software 6.2 was used to simulate the water retentive curves (Reeve and Carter, 1991) of soil simulated according to single porosity model. The fitness of the model was relied on the r^2 values. The means of different treatments were compared using standard error values.

RESULTS

The water retentive curves (WRC) prepared from soil moisture contents at different pressures ranging from 0.33-15 bars are presented in Figures 1, 2 and 3 for control, qemisoyl, compost, FYM and gypsum and all possible combinations of the soil additives, respectively. The data regarding soil moisture at saturation, field capacity, permanent wilting point and plant available water derived from soil moisture characteristic curves are presented and discussed below.

Control (no additive)

Qemisoyl @ 15 kg ha^{-1}

FYM @ 25 Mgha^{-1}

Compost @ 0.75 Mgha^{-1}

Gypsum @ 2.5 Mgha^{-1}

Figure 1. Water retentive curve for control (no additive) and soil additives viz. qemisoyl, farm yard manure, compost and gypsum when used singly.

Qemisoyl + FYM

Qemisoyl + Compost

Qemisoyl + Gypsum

FYM + Compost

FYM + Gypsum

Compost + Gypsum

Figure 2. Water retentive curve for soil additives viz. qemisoyl, farm yard manure, compost and gypsum when used in dual combination.

Qemisoyl + FYM + Compost

Qemisoyl + FYM + Gypsum

Qemisoyl + Compost + Gypsum

FYM + Compost + Gypsum

Qemisoyl + FYM + Compost + Gypsum

Figure 3. Water retentive curve for soil additives viz. qemisoyl, farm yard manure, compost and gypsum when used in triple and quad combinations.

Table 1. Soil moisture contents under different soil additives at various stages

Treatments*	Soil moisture content ($m^3\ m^{-3}$)			
	At Saturation	At Field Capacity	At Permanent Wilting Point	Plant Available Water
Soil (no additive)	0.410±0.023	0.251±0.012	0.128±0.013	0.123±0.012
Qemisoyl @ 15 kg ha^{-1}	0.440±0.013	0.284±0.002	0.146±0.002	0.138±0.002
FYM @ 25 $Mgha^{-1}$	0.435±0.023	0.272±0.003	0.140±0.011	0.132±0.010
Compost @ 0.75 $Mgha^{-1}$	0.424±0.001	0.276±0.015	0.140±0.009	0.136±0.012
Gypsum @ 2.5 $Mgha^{-1}$	0.430±0.014	0.274±0.021	0.143±0.012	0.131±0.012
Qemisoyl + FYM	0.434±0.015	0.276±0.021	0.142±0.003	0.134±0.006
Qemisoyl + Compost	0.435±0.031	0.275±0.015	0.144±0.014	0.131±0.007
Qemisoyl + Gypsum	0.440±0.023	0.279±0.006	0.142±0.006	0.137±0.009
FYM + Compost	0.443±0.032	0.273±0.009	0.141±0.011	0.132±0.011
FYM + Gypsum	0.442±0.027	0.276±0.016	0.143±0.000	0.133±0.021
Compost + Gypsum	0.433±0.019	0.272±0.021	0.144±0.014	0.128±0.003
Qemisoyl + FYM	0.434±0.018	0.274±0.030	0.139±0.002	0.135±0.003
Qemisoyl + FYM + Gypsum	0.442±0.015	0.276±0.001	0.140±0.003	0.136±0.007
Qemisoyl + Compost + Gypsum	0.441±0.001	0.275±0.006	0.141±0.004	0.134±0.031
FYM + Compost + Gypsum	0.439±0.003	0.274±0.006	0.142±0.013	0.132±0.004
Qemisoyl+FYM+Compost +Gypsum	0.443±0.051	0.277±0.021	0.143±0.014	0.134±0.003

*Application rates for combinations of various soil additives (Qemisoyl, FYM, Compost, Gypsum) are same as given in earlier treatments (1 to 5)

Soil moisture at saturation: The soil moisture at saturation influenced by the application of different soil additives is given in Table 1. Qemisoyl @ 15 kg ha^{-1} and its combination with FYM @ 25 Mg ha^{-1}, compost @0.75 Mg ha^{-1} and gypsum @ 2.5 Mg ha^{-1}gave saturated water content of 0.44 m^3 m^{-3}each that was higher than other treatments. Least saturated water content of 0.41 m^3 m^{-3} was observed in soil with no additive. Overall saturated water content in soil samples treated with additives was higher than samples with no additive.

Soil moisture at field capacity: The data regarding soil moisture contents at field capacity influenced by the application of different soil additives is given in Table 1. The highest water contents at field capacity (0.28 m^3m^{-3}) were recorded for Qemisoyl @ 15 kg ha^{-1} and compost @ 0.75 Mg ha^{-1} and it was at par with different combinations of soil additives. Least water content of 0.25 m^3 m^{-3} at field capacity was observed in soil with no additive. Overall water contents at field capacity measured in soil samples treated with additives were higher over control.

Soil moisture at permanent wilting point: The data regarding soil moisture contents at permanent wilting point influenced by the application of different soil additives is given in Table 1. Highest water contents at permanent wilting point (0.15 m^3 m^{-3}) were recorded for Qemisoyl @ 15 kg ha-1 and least water content of 0.13 m^3 m^{-3} at permanent wilting point was observed in soil with no additive. While water contents at permanent wilting point were at par with each other for other soil additives (Compost, FYM and Gypsum) and all possible combinations. Overall water contents at permanent wilting point measured in soil samples treated with additives were higher than samples with no additive.

Plant available water: The data regarding plant available soil moisture contents is given in Table 1. Highest plant available water contents (0.14m^3m^{-3}) were recorded for Qemisoyl@ 15 kg ha-1and compost @ 0.75 Mg ha^{-1} and it was at par with different combinations of soil additives. While plant available water contents (0.13m^3 m^{-3}) were at par with each other for other soil additives (FYM and Gypsum) and some other combinations. Least water content of 0.13 m^3 m^{-3} at permanent wilting point was observed in soil with no additive. Over all plant available water contents measured in soil samples treated with additives were higher than samples with no additive.

DISCUSSION

Contrary to our hypothesis the dual, triple and quad combination of Qemisoyl, farm yard manure, gypsum and compost amendments showed non-significant difference in water absorption and retention in the soil than their sole applications. While comparing various aspects of our soil additives, Qemisoyl retains more water and can be efficiently applied as it has to be used in much lower quantity as compared to the conventional use of farm yard manure or compost. Under field application the combined use of these additives might only increase labour, transportation and application cost, thus use of single soil additive for soil moisture conservation seems more preferred choice.

The improvement in soil water retention at saturation, field capacity and permanent wilting point have been repeatedly reported with the application of hydrogel, FYM, gypsum and compost (Anabayan and Palaniappan, 1991; Rashid *et al.,* 2008; Albaladejo *et al*., 2012). It appeared that the application of amendments improved soil physical conditions for enhanced water availability as reported by Brady and Weil (2014).

Among the soil amendments, Qemisoyl appeared superior for better soil water retention as compared to compost, gypsum and farm yard manure. The synthetic polymers improve soil water retention and availability because they can absorb large quantities of water as compared to their own mass. Qemisoyl can absorb water upto 400 times of its original mass and has the potential to release up to 95% of the absorbed water to soil (Monning, 2005).

In fact, these polymers possess hydrophilic properties which help them to capture and retain additional water. When water comes in contact with these polymers, electrical repulsion takes place due to positive and negative charges present over there, causing the main branches of the polymer molecule to repel each other like the poles of a magnet. Consequently, water moves in between the braches resulting in swelling of the gel (Pitchard and Quinn, 2003), this absorbed water becomes available afterward on drying. Polymers also affect the soil properties like water infiltration, bulk density, aeration, size and the number of aggregates (Abedi *et al.,* 2008, Narjary *et al.,* 2012) that has an additive effect on plant available water content. The polymers increase the pore space as a result of alternate expansion and contraction which in turn affect the bulk density of the soil (Chaudhry, 1992), when the bulk density of the medium is decreased the water retention capacity is further enhanced.

***Conclusion*:** The results indicated that higher moisture can be retained in the rooting media with the application of soil additives especially Qemisoyl which could be utilized to achieve higher levels of soil water retention and availability for crop production in severely vulnerable and drought prone ecology of rainfed areas. Furthermore, the combined use of various soil additives did not show any superiority over their sole application. However, comprehensive field studies based on results of present laboratory study may help develop useful water harvesting/capturing interventions at farm scale.

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REFERENCES

Abedi, K.J., S.S. Eslamian and J. Asadkazemi. 2008. Enhancing the available water content in unsaturated soil zone using hydrogel, to improve plant growth indices. Ecohydrol. Hydrobiol. 8:67-75.

Albaladejo, J., R. Ortiz, N. Garcia-Franco, A.R. Navarro, M. Almagro, J.G. Pintado and M. Martínez-Mena. 2012. Land use and climate change impacts on soil organic carbon stocks in semi-arid Spain. J. Soils Sediments 13:265–277.

Anabayan, K. and S.P. Palaniappan. 1991. Effect of application of coir compost, enriched farm yard manure and an hydrophilic polymer on soil moisture content, growth and yield of rainfed sorghum in association with Azospirillum. J. Agron. Crop Sci. 166:112-116.

Blum, A. 2009. Effective use of water (EUW) and not water use efficiency (WUE) is the target of crop yield improvement under drought stress. Field Crop Res. 112:119-123.

Brady, N.C. and R.R. Weil. 2014. The Nature and Properties of Soils. Prentice Hall Inc, New Jersey.

Chaudhry, M.A. 1992. Effect of hydrogels on moisture and fertilizer use efficiency in loess soils. Ph.D. Thesis. Quaid-e-Azam University, Islamabad, Pakistan.

Deksissa, T., I. Short and J. Allen. 2008. Effect of soil amendment with compost on growth and water use efficiency of amaranth. In: Proceedings of the UCOWR/NIWR Annual Conference: International Water Resources: Challenges for the 21st Century and Water Resources Education, July 22 – 24, 2008, Durham, NC.

EL-Hady, O.A. and S.A. Abo-Sedera. 2006. Conditioning effect of composts and acrylamide hydrogels on a sandy calcareous soil. II. Physico-bio-chemical properties of the soil. Int. J. Agri. Biol. 8:876-884.

Kijne, J.W., R. Barker and D.J. Molden. 2003. Water Productivity in Agriculture: Limits and Opportunities for Improvement. CABI, UK, p.332.

Monnig S. 2005. Water saturated super-absorbent polymers used in high strength concrete. Otto- Graf- J. 16:193-202.

Narjary, B., P. Aggarwal, A. Singh, D. Chakraborty and R. Singh. 2012. Water availability in different soils in relation to hydrogel application. Geoderma 187–188:94–101.

Nizami, M.M.I., M. Shafiq, A. Rashid and M. Aslam. 2004. The soils and their agricultural development potential in Potwar. NARC, Islamabad, Pakistan; pp.5-7.

Pitchard, J.F. and J.J. Quinn. 2003. Terrasorb, the super soil moisturizer. A report on the product and new technology; pp.1-16.

Rashid, M., M.N. Iqbal, M. Akram, M. Ansar and R. Hussain. 2008. Role of gypsum in wheat production in rainfed areas. Soil Environ. 27:166-170.

Reeve, M.J. and A.D. Carter. 1991. Water release characteristic. In: K.A. Smith and C.E. Mullins (eds.), Soil Analysis: Physical Methods. Marcel Dekker. Inc. 270 Madison Avenue, New York; pp.111-160.

Shahbaz, K. and M.A. Hanjra. 2009. Footprints of water and energy inputs in food production-Global perspective. Food Pol. 34:130-140

Sharif, M., M. Ahmed, M.S. Sharif and R.A. Khattak. 2004. Effect of organic and inorganic fertilizers on the yield and yield components of maize. Pak. J. Agric. Agril. Engg. Vet. Sci. 20:11-15.

Sharma, J. 2004. Establishment of perennials in hydrophilic polymer-amended soil. SNA Res. Conf. 42:530–532.

Yu, J., T. Lei, I. Shainberg, A.I. Mamedov and G.J. Levy. 2003. Infiltration and erosion in soils treated with dry pam and gypsum. Soil Sci. Soc. Am. J. 67:630-636.