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IDENTIFICATION OF ORGANIC HYDROGEL CHARACTERISTICS AS A SOIL CONDITIONER ON PHYSIO-CHEMICAL INCEPTISOLS

Abraham Suriadikusumah*, O. Mulyani** and H.E. Hidayat Salim**

Abstract: A study on organic hydrogel, a product of the Indonesian Institute of Science (LIPI), was conducted to measure its efficiency as a soil conditioner; the physio-chemical characteristics of inceptisol soil in Jatinangor area. The experiment was conducted from June to October 2014 at the garden Laboratory of Universitas Padjadjaran in Jatinangor located approximately 750 m above sea level. It consisted of two treatment factors: the percentage of hydrogel to soil weight, measured at four levels (0%, 0.1%, 1%, and 5% of the soil weight); and the placement of the hydrogel on the soil, conducted in three conditions (at the surface of the soil, at a 15 cm depth, and at a 30 cm depth). The treatment employed Factorial Patterns of Randomized Block Design and was repeated four times. The parameters of responses examined included: C-organic (%), N-total (%), pH, KTK (cmol kg^{-1}), water level, aggregate stability, and soil permeability. The results indicated that there were interactions between the two treatments and the parameters of pH, KTK, and water level of inceptisol soil; but there was no interaction with the other characteristics (C-organic, N-total, aggregate stability, and permeability of the soil).

Keywords: Proportion and placement of hydrogel, organic hydrogel, incubation time, and inceptisol soil characteristics.

INTRODUCTION

The use of super absorbent hydrogel is common in various fields. It is used in waste management, plantation soil, reduction of friction in piping, waterproof coating, protection of underground cables, packaging, fire extinguishers, irrigation, and the health industry (since it is non-toxic, biodegradable, and bio-compatible) (Suwardi et. al., 2008, Erizal et. al., 2013). One of the factors that make super absorbent polymer an important element in solution bonds is the active group (-COOH) it contains. Super absorbent polymer plays a big role in binding water molecules; such an active group is called a hydrophilic group (Swantomo, 2008). Researchers have studied various raw materials to find the best formula for an environment-friendly, durable, and highly-hydrophilic hydrogel. For instance, Swantomo (2008) combines polyacrylamide and natural zeolites through *pengion* irradiation technique (electron beam irradiation) to obtain a polymer with good physical and stability characteristics. Another example is a study on water-absorption of hydrogel using the Taguchi model to create a high water-absorbent hydrogel (Pourjavadi et. al. 2010).

* *Corresponding author:* Department of Soil Science, Faculty of Agriculture, Padjadjaran University. *Email: abrahakusuma@gmail.com*

** Department of Soil Science, Faculty of Agriculture, Padjadjaran University

Super absorbent hydrogel can also be used to provide water supply for plants. This is one of the reasons for hydrogel use in agriculture. A study to provide water supply system for plants concerning hydrogel was conducted by Chirino et. al., (2010), who shows the highest result of water-binding capacity of roots, water-content in seeds, and seed's endurance in the field due to the application of hydrogel through a media of soil mixed with standard lime peat and coconut peat with the ratio of 1:1 v/v and two doses of hydrogel Stockosorb® K-400 (0.7 and 1.5% w/w). Other studies were performed by Agaba et. al., (2011) and Durovic et. al., (2012), proving that the application of hydrogel can improve the water-binding and water-retaining abilities of sandy soil, peat moss soil, and chernozem as soil matrix to reduce the frequency of water-discharge.

Hydrogel decomposition is another interesting topic to analyze because it is an important factor in its function as a water-releasing tool. Different research on this topic was conducted by Subagio (2009) and Mohadi (2007). Subagio (2009) found a significant effect, of 6-8 MST after watering using hydrogel on castor-oil plants. However, it does not have a real effect on the general parameter of agronomy due to the decomposition of the hydrogel by microbes in the soil. Natural decomposition of hydrogel is possible because the hydrogel is a natural one, with not-too-strong bonds; which is why many current researchers switch to synthetic hydrogel that is more superior to the natural one. The decomposition of synthetic hydrogel occurs in two ways. Considering the bonds of the hydrogel, in low pH, hydrogel created with chemical bond is harder to decompose (dissolve) than that created with physical bond (Mohadi, 2007). Since the use of organic and environment-friendly hydrogel is better than the synthetic one, analysis of its characteristics as a meliorant agent is important.

This study specifically aims to examine the characteristics of hydrogel incubated in the soil and its effects on the characteristics of the soil without plants. It will be useful as a basic reference to provide fertilizers and water to plants through hydrogel application.

RESEARCH METHOD AND MATERIAL

The preliminary experiment, on laboratory scale was conducted in the Chemical and Soil Fertility Laboratory in the Faculty Agriculture of UNPAD and the Indonesian Institute of Science (LIPI). The green-house experiment was conducted in the Greenhouse of the Faculty Agriculture at UNPAD in Jatinangor. The materials involved in these experiments were organic hydrogel (cellulose-based), and chemicals for laboratory analysis. The equipment used in the study (in the field, laboratory, and the greenhouse) are detectors of UV/VIS with a wave length (λ) of 259.5 nm, centrifuge, Atomic Absorption Specter-photometer (AAS), oven, analytical scale, mechanical scale, excicator, a set of dry sieves, glass apparatus and writing equipment.

The experiment utilizes the Factorial Pattern of Randomized Block Design with two treatments: the percentage of hydrogel in the soil (W) with four levels (W1, W2, W3, and W4) and the placement of hydrogel in the soil (F) with three levels (F1, F2, and F3). The combination of the treatments is displayed in the following Table 1.

TABLE 1: COMBINATION OF TREATMENTS

Percentage of Hydrogel (W)	*Placement of Hydrogel in the soil (F)*		
	F1: 0 cm depth (on the surface of the soil)	*F2: 15 cm depth (under the surface of the soil)*	*F3: 30 cm depth (under the surface of the soil)*
W1 : 0 % hydrogel (control)	W1F1	W1F2	W1F3
W2 : 0,1% hydrogel/sack	W2F1	W2F2	W2F3
W3 : 1% hydrogel /sack	W3F1	W3F2	W3F3
W4 : 5% hydrogel /sack	W4F1	W4F2	W4F3

There are twelve combinations of treatments, repeated three times so there are 36 units of experiment. The weight of the soil in each sack is 2 kg. The parameter of responses examined are: C-organic (%), N-total (%), pH, KTK (cmol kg^{-1}), water level (%), aggregate stability, and soil permeability (cm $hour^{-1}$). These characteristics of soil are determined through the methods in Table 2.

TABLE 2: METHODS TO DETERMINE SOIL CHARACTERISTICS

No.	*Soil characteristics*	*Methods*
1.	C-organic (%)	Wilkley & Black
2.	N-total (%)	Kjeldahl
3.	pH	Potentiometry
4.	KTK (cmol kg^{-1})	Atomic absorption specter-photometer (AAS)
5.	Water level (%)	Volumetric, gravimetric
6.	Aggregate stability	wet sieving, “Vilensky” method
7.	Permeability (cm $hour^{-1}$)	Permeameter

FINDINGS AND DISCUSSION

Characterization of Organic Hydrogel on a Laboratory Scale

This experiment is the most basic step in finding hydrogel that qualifies as a slow-release water and fertilizer retention agent. The hydrogel produced by LIPI should be tested for absorption level using volumetric and gravimetric methods. At this stage, the produced hydrogel is on laboratory scale (in limited quantity).

The organic hydrogel used in this study is a product of a joint-research of UNPAD and LIPI Bandung. It has been tested and modified several times to adjust it to the agricultural needs. The main material used in the production of this hydrogel is cellulose from sugar cane. The result of the water-absorption test of the previous hydrogel (Suriadikusumah et. al., 2014) is almost 32 times the hydrogel weight (swelling ratio 1:32), in 240 minutes (4 hours). The weakness of this product is its brittle texture, dissolving after 120 minutes of being submerged. The hydrogel product used in this study is a result of the second-level modification on laboratory scale, with lower absorption (14 times the hydrogel weight) and longer endurance (up to 6 hours of submersion). Its swelling ratio is low, considering that other products can absorb water up to 100 times their weights (Heriyanto et. al, 2015).

Preliminary Analysis of Soil

Based on the preliminary soil analysis (prior to the greenhouse experiment), it was found that the inceptisol soil has a pH level of 4.8 (quite acidic), C-organic of 0.42%, C/N ratio of 7, and N-total of 0.2% (low). Its available-P Level is 11.8 ppm (low), its P_2O_5 potential is 33.1 mg 100 g^{-1} (medium), its KTK is 24.18 cmol kg^{-1}, its exchangeable cations such as Na, K and Mg levels are 0.3 cmol kg^{-1}, 0.1 cmol kg^{-1} (low) and 3.7 cmol kg^{-1} (high), respectively, and its saturated alkali is 29.67% (low). In general, these results of the preliminary analysis of the soil indicate that inceptisol soil is a potential plantation media; however, it needs to go through a process of refinement to make it more suitable to grow plants.

The Effect of Hydrogel Proportion and Placement on Soil Characteristics

The examination of soil characteristics is conducted 30 days after the hydrogel has been incubated in the soil in sacks. This 30-day incubation time is determined based on the results of the previous study by Mulyani et. al., (2014) which shows the best results for chemical characteristics of soil after hydrogel application. Prior to incubation, hydrogel is saturated with water for 6 hours, resulting in water absorption of up to 14 times the hydrogel weight.

C-organic of the Soil

The statistical analysis of C-organic characteristic of the soul indicates that there is no interactional effect of the depth of application and the hydrogel percentage. It means that the depth of placement and the percentage of hydrogel do not affect the C-organic level of the soil. The individual effect of each treatment can be seen in Table 3.

TABLE 3: INDIVIDUAL EFFECT OF PERCENTAGE AND PLACEMENT OF HYDROGEL ON C-ORGANIC AND N-TOTAL OF THE SOIL

Treatment	*C-organic (%)*	*N-Total*
Hydrogel percentage		
W1: 0%	0.880 a	0.197 a
W2: 0.1%	0.901 a	0.199 a
W3:1%	0.908 a	0.208 a
W4: 5%	0.950 a	0.199 a

Treatment	C-organic (%)	N-Total
Hydrogel placement		
F1: 0 cm depth	0.865 a	0.198 a
F2: 15 cm depth	0.979 a	0.207 a
F3: 30 cm depth	0.885 a	0.198 a

From the above table, it can be noted that, the numbers with a similar letter-mark have no significant difference according to the Duncan test; at 0.05 significance level. There is no interaction between the two treatments and the soil C-organic may be due to the insignificant difference in temperature of each treatment (24.94°C – 25.33°C). Soil temperature is the main factor for decomposition rate of organic matter in the soil. A significant effect on C-organic will be found if each treatment has a temperature difference of 5°C – 10°C (Roberts, 2011). Generally, hydrogel application can improve the soil C-organic level. The preliminary analysis of inceptisol soil shows that the preliminary C-organic level is 0.42%. After hydrogel application on the soil, its C-organic level doubles. The treatment that produces the highest C-organic is the application of hydrogel at 15 cm under the surface of the soil. As time passes, the applied hydrogel will be decomposed and increase the level of C-organic in the soil. The treatment of hydrogel at 15 cm under the surface of the soil increases the C-organic level from 0.42% to 0.97%, equivalent to 133.1% increase. This treatment yields the highest result because there are more biological activities and more micro-organisms in the depth of 15 cm, compared with the depth of 0 cm (the surface) or 30 cm (the bottom of the soil) (Suseno, 2008). The high level of biological activity indirectly affects the decomposition of organic hydrogel, resulting in the increase in C-organic level.

N-Total of the Soil

The statistical analysis indicates that there is no interaction between the treatments of placement and percentage of hydrogel and the N-total of the soil. The individual effect of placement and percentage of hydrogel on N-total also shows insignificant results (Table 3). The sugar cane cellulose-based organic hydrogel only contains 12.73% – 15.77% of nitrogen in 1 gram of sample. In other words, each gram of hydrogel contains 0.127 – 0.157 gram of nitrogen (Andriyanti et. al., 2012), which is insufficient to significantly increase the overall N-total of the soil.

pH of the Soil

Statistical analysis of the data on pH indicates that there is an interaction between the treatments (percentage and placement of hydrogel) and the pH level of the soil (Table 4).

TABLE 4: EFFECT OF PERCENTAGE AND PLACEMENT OF ORGANIC HYDROGEL ON PH LEVEL OF THE SOIL

Percentage (W)	*Placement (F)*		
	F1 (0 cm)	*F2 (15 cm)*	*F3 (30 cm)*
W1 (0%)	5.67 a A	5.59 a A	5.68 a A
W2 (0.1%)	6.35 c B	5.85 a A	5.84 b A
W3 (1%)	6.37 c A	6.79 c B	6.21 c A
W4 (5%)	6.10 b A	6.40 b B	6.47 d B

From the above table, it is also noted that, the numbers marked with similar letters (capital letters horizontally and lower-case letters vertically) are not significantly different according to the Duncan test on the significance level of 0.05.

Overall, the application of hydrogel in the soil can improve the pH level; as indicated by the percentage treatments (W2, W3, and W4) at the depths of 0 cm (F1), 15 cm (F2), and 30 cm (F3) that yield higher pH than the control treatment of W1 (0%) at the same depths. Table 4 also shows that the percentage treatment of 1% (W3) is relatively better in affecting pH. The increase of pH level in the soil is directly proportional to the increase in the percentage of hydrogel up to 1%. The decomposition of organic hydrogel in the soil will increase the level of humic acid (Suntoro, 2003). The increase in humic acid will increase pH level. However, in abundant level, it can also decrease pH level in the soil (Anjana et. al., 2014). This is why the pH level in the soil returns to normal with treatment of 5% hydrogel.

The change in pH level, from acidic to neutral, is due to the decrease of H^+ ions and the increase of OH^- ions as a result of organic matter decomposition. The increase in OH^- ions will increase pH level of the soil. In addition, pH level also increase because the organic matter from hydrogel decomposition contains negative contents of organic colloid, which binds H^+ ions, resulting in the decrease of soil acidity (Ritchie and Dolling, 1985).

The best combination of treatments is 1% percentage (W3) placed at 15cm (F2) under the surface of the soil. The application of hydrogel at 15 cm depth yields the highest pH level, compared with other depths, because at that level, the soil contains higher C-organic level due to the high level of decomposer microorganism activity. The high level of biological activity will accelerate decomposition of hydrogel. In other words, it will provide organic colloid faster to bind the H^+ ion, so that pH level of the soil will turn to neutral (Suseno, 2008).

KTK of the Soil

Statistical analysis of KTK indicates that there is an interaction between the treatments (the depth of placement and percentage of hydrogel) with the KTK level (Table 5). Interaction between the two treatments means that the hydrogel percentage and its placement affects the KTK level of the soil. In general, the soil in which hydrogel is applied (W2, W3, and W4) has higher KTK than the control soil (W0) at depths of 0 cm, 15 cm, and 30 cm (F1, F2, and F3).

TABLE 5: THE EFFECT OF PERCENTAGE AND PLACEMENT OF ORGANIC HYDROGEL ON KTK LEVEL OF THE SOIL

Percentage (W)	*Placement (F)*		
	F1 (0 cm)	*F2 (15 cm)*	*F3 (30 cm)*
W1 (0%)	22.63 a	22.25 a	25.56 b
	AB	A	B
W2 (0.1%)	22.72 a	22.61 a	23.42 ab
	A	A	A
W3 (1%)	22.86 a	26.29 b	24.57 b
	A	B	AB
W4 (5%)	25.62 b	24.27 ab	21.68 a
	B	AB	A

The numbers marked with similar letters (capital letters horizontally and lower-case letters vertically) are not significantly different according to the Duncan test on the significance level of 0.05.

The difference of the KTK level on the treatment of 0% hydrogel from those of 0.1%, 1%, and 5% is not significant. It may be due to the applied hydrogel has not being fully decomposed. The increase of the KTK level is caused by the acceleration of organic matter decomposition; in which the hydrogel decomposition yields organic colloid that increases the KTK level of the soil (Pramono, 2014). The combination of 15cm placement and 1% hydrogel yields a higher level of KTK, compared with other interactions. The combination increases the KTK up to 8.73%, which puts it in the medium category. This increase is directly connected to the increase of organic material in the soil and the change of pH to neutral. Higher level of organic material and neutral pH in the soil will result in high KTK level (Hartati et. al., 2013).

Water Level of the Soil

Statistical analysis shows that there is an interaction between the two treatments, which means that the treatments (percentage and placement of hydrogel) affect the water level of the soil. The interactions between the two factors of the treatment on the water level parameter are displayed in Table 6.

TABLE 6: THE EFFECT OF PERCENTAGE AND PLACEMENT OF ORGANIC HYDROGEL ON WATER LEVEL OF THE SOIL

Percentage (W)	*Placement (F)*		
	F1 (0 cm)	*F2 (15 cm)*	*F3 (30 cm)*
W1 (0%)	8.53 a B	9.38 a B	7.69 a A
W2 (0.1%)	9.53 a A	9.63 a A	10.97 a A
W3 (1%)	11.92 b A	18.33 b B	16.75 b B
W4 (5%)	26.07 c B	24.68 c B	18.66 b A

The Table 6 shows that numbers marked with similar letters (capital letters horizontally and lower-case letters vertically) are not significantly different according to the Duncan test on the significance level of 0.05.

In general, the effect of hydrogel application on the water level of the soil indicates that the higher percentage of hydrogel applied, the higher the level of the water in the soil will be. Application of hydrogel in the percentage of 0% (W1), 0.1% (W2), and 1% (W3) shows that the highest water level will be at the depth of 15 cm. However, with a 5% of hydrogel, the highest water level is at the depth of 0 cm (F1). The mechanism of water retention is directly related to the level of organic matter contained in the soil. This is congruent with Refliaty et. al., (2011) who state that the increase in organic material will refine the structure of the soil; which will improve its porosity and water-retaining capacity. In this study, the best interaction is between 5% of hydrogel (W4) and the depth of 0 cm (F1), which can increase water level from 6% to 26.07%, equivalent to 334.5%. This may be due to the high concentration of hydrogel. The high percentage of hydrogel at the surface of the soil causes the water level to be very high, so that it is easier and faster for the water to seep through the soil up to certain depths due to gravity. In addition, Gilbert et. al., (2014) note that the higher the percentage of hydrogel applied in the soil, the higher the water level will be.

Aggregate Stability of the Soil

Statistical analysis indicates that there is no interaction between the percentage and the placement of hydrogel on the aggregate stability parameter (Table 7). Individually, we can see that the effect of hydrogel on aggregate stability in each treatment has no significant effect. Aggregate stability is the level of physical and mechanical disintegration of the soil (Baver et. al, 1972). In this study, the treatment has no significant effect on soil aggregate stability due to the high level of environmental influences, such as the temperature of the greenhouse. The utilization of hydrogel in agriculture has been performed for a long time, and the hydrogel is continuously improved to make it more suitable with the needs in the field. Natural hydrogel has various benefits, including the minimization of soil erosion and run off, high level of water retention, efficient water usage, improvement of soil characteristics, reduction of irrigation use, and to soften the soil (Jhurry, 1997). The findings of the study confirm this. The more hydrogel applied, the higher the aggregate stability the soil, and the deeper it is placed, the lower the aggregate stability.

TABLE 7: INDIVIDUAL EFFECT OF ORGANIC HYDROGEL COMPOSITION AND PLACEMENT ON AGGREGATE STABILITY OF THE SOIL

Treatment	*Aggregate Stability*	*Permeability*
Hydrogel percentage		
W1: 0%	13.47 a	5.75 a
W2: 0.1%	13.33 a	5.23 a
W3:1%	13.33 a	5.11 a
W4: 5%	13.00 a	5.06 a
Hydrogel placement		
F1: 0 cm depth	13.67 a	5.39 a
F2: 15 cm depth	13.33 a	5.31 a
F3: 30 cm depth	13.00 a	5.42 a

In Table 7, it can be noted that the numbers marked with similar letters are not significantly different according to the Duncan Test on significance level of 0.05.

Permeability of the Soil

There is no interaction between the composition and the placement of hydrogel on the parameter of soil permeability. Permeability is the speed with which water passes the pores of soil. It is influenced by the size of the pores, the type of the soul, and the density of the soil. In this study, individual composition and placement of hydrogel has no significant effect on soil permeability (Table 7). The physical characteristic of the soil, such as its texture, plays an important role in determining soil permeability. The soil used in this study belongs to the Ultisol order, with a texture of dusty clay, containing 4% of sand, 30% of clay, and 66% of dust. With such contents, it will be harder for water to pass (permeate) the pores of the soil. Hydrogel can bind water better in the pores of the soil, as proven by Jhurry (1994) who notes that only 5% of water can permeate hydrogel and that hydrogel can bind water up to more than 300 times its original weight. The more hydrogel applied in the soil, the more water can be retained. This is in line with Zhang and Miller (1996) who state that environmental factors, including temperature, have big effects on hydrogel application. High temperature may cause the applied hydrogel not to have a significant effect on the soil because it will not be able to hold water permeability due to the low mechanism of soil aggregate and hydrogel binding.

CONCLUSION

There are interactions between the percentage and the placement of hydrogel in the soil on the parameters of pH, KTK, and water level of inceptisol soil. Meanwhile there is no interaction on the parameters of aggregate stability and permeability of the soil. There is no significant individual difference of the placement and percentage of hydrogel in the soil on the parameters of C-organic, N-total, aggregate stability, and permeability of inceptisol soil.

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