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# Soil Water Management to Minimize Shrinkage of Vertisols

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**ABSTRACT**

The high level of clay and the predominance of 2:1 montmorillonite clay on the soil affect the swelling and shrinking of Vertisols soils, inhibiting plant rooting. This study aims to determine the way of giving and the amount of water in Vertisols soil from Jeneponto Regency, Province of South Sulawesi, Indonesia. This research is an experimental pot in a greenhouse, Faculty of Agriculture, Hasanuddin University, Indonesia. This study used a two-factor block random design method, namely the water provision factor consisting of 2 treatments and the water content factor consisting of 4 treatments with three repeats so that 24 treatment pots were obtained. The water is given through the surface and drops with a water content of 100%, 75%, 50%, and 25% of the field capacity. The results showed that the Vertisols Jeneponto had an available waterwater content of 24.60% (field capacity water content of 40.80% and permanent wilting point of 16.20%) with a clay content of 82%. The water provision method affects the width and depth of the fracture as the vegetative and root growth of maize. The results also showed that continuously applying water in limited quantities (drips method with a water content of 75% of field capacity) directly into the root area of plants can suppress the occurrence of shrinking and increase vegetative and root growth of maize as well as the use of a smaller amount of water compared to the surface method.

Keywords: shrinking, swelling, Vertisols, water content.

## 1. INTRODUCTION

Plants need soil management, including water supply, and affect soil properties, especially those related to soil density, water storage and groundwater resistance. One soil type that needs improvement in its use is the Vertisols soil type. Vertisol is a high clay type of soil and is generally composed of a 2:1 clay mineral, mainly smectitic mineralogy with a high water holding capacity but also with a high water resistance available to plants. The low water supply for plants, especially in relatively dry areas, means that plants with a lack of water cannot grow optimally. Soil research staff (2014); Prasetyo (2007); Wubetu (2017) characterizes Vertisols as a type of soil that is dark gray to blackish, >30% clay, smooth-sided; and fractures that can periodically open and close, with a clay mineral composition dominated by 2:1 type clay minerals.

Vertisols have and also characterize deep and wide fissures and have a gilgai microrelief with frequent microhills and microvalleys (Wubetu, 2017). These soils have distinctive cyclic tarsi that distinguish them from other soils. Vertisols are soils whose prospects may be quite good due to their chemical properties, but the constraint in soil management, which is relatively difficult due to the influence of the physical properties of these Vertisols. Based on the results of field surveys, the soil is hard under dry conditions with surface cracks 1 cm wide and 10 to 50 cm deep. This condition became a serious constraint for farmers in growing crops because it affected the productivity of the crops. Cracking problems occur due to the unavailability of water, which affects the physical properties of Vertisols. According to Mukanda and Mapiki (2001), the difficulty of the physical properties of this soil is in the form of heavy clay structure, swelling and shrinking properties, low infiltration rate and slow water drainage.

Other limitations on Vertisols are environmental factors, namely naturally limited water availability and heavy soil management. The nature of the clay mineral, montmorillonite, affects these limitations. The negative impact of montmorillonite shrinkage on agricultural cultivation is that wide cracks break root tissue for annual plants (Sunarminto & Santosa, 2008). Vertisol's soil management must minimize cracks by regulating the water supply. According to Jasminarni (2008), the water requirement of plants is measured by the percentage water content of the field capacity. In addition, from the results of research by Suwarto (2003), it was reported that the highest corn growth yield was obtained when treating field-capacity soil conditions. This soil requires excellent and proper water management to be suitable for plant growth.

## 2. MATERIALS AND METHODS

This research is an experimental research conducted in the greenhouse of the Faculty of Agriculture, Hasanuddin University, Makassar, Indonesia. Soil samples were collected from a depth of 60 cm from Bangkala District, Jeneponto Regency, South Sulawesi Province, Indonesia (location in Figure 1) and then placed in a pot experiment. The study used a factorial block random design with two factors, namely the factor of giving water (irrigation) up to two treatments, M1 = flush on the surface and M2 is dripped. The water content factor of four treatments is A1 (field capacity, FC) is 1060.8 $m^3$ $ha^{-1}$, A2 or 75% FC is 795.6 $m^3$ $ha^{-1}$, A3 or 50% FC is 530.4 $m^3$ $ha^{-1}$, A4 or 25% FC is 265.2 $m^3$ $ha^{-1}$. The treatment combinations were eight and each treatment combination was replicated three times to give 24 trial pots.

The removed soil is composed of stones or the roots of the plants carried. Then puree and then put in a pot of 10 kg. A portion of the soil is taken for analysis of physical properties. Place the soil in a pot and then plant corn seeds 5 cm deep, up to 2 seeds per pot. Until now, an infusion device with a drip time difference adapted to the treatment was coupled for drop treatment. Fertilization takes place three days after planting with an N fertilizer dose of 300 kg $ha^{-1}$. Fertilizer is dipped 5 cm deep into the soil in a circle at a distance of 5 cm from the seed and again covered with soil.


Fig 1. Vertisols soil sampling location (red dot)

Irrigation is performed to manage the moisture water content of the growing medium after treatment. The moisture-water content in the planting medium should remain constant during the observation. For the treatment of irrigation water on the surface, the application of water according to the treatment is continued every three days after watering (according to the preliminary observations made where cracks in the soil begin to appear on the third day after watering). For the drip treatment, water is added daily until it reaches the moisture water content according to the treatment while the time limit is still adjusted from the initial observation determination of the moisture water content in the treatment based on the field capacity percentage. Gravimetric methods determine the field capacity of water content. The separation of water by heating is commonly referred to as the gravimetric method and is a direct measurement method (Topp & Ferre, 2002). The gravimetric method is conceptually the simplest method for determining the moisture-water content of the soil. Observations include measurements of plant height, taken once a week, and observations of cracks on the soil surface, made before watering. Corn height was measured from the lower basal stems (boundary to the soil surface) to the top of the top leaf. Harvesting occurs after reaching the flowering stage around 64 DAP (the day after planting). After harvesting, the roots of the plant were cleaned of the remaining soil before measuring the length of the roots. The length of the roots was measured in a fresh and clean condition of the soil. The root hairs are not measured. The root length was measured according to the root structure in the root system according to the classification of Rao and Ito (1998), which consists of main root (taproot), primary root, secondary root and tertiary root. In this experiment, root length was measured by measuring only the length of the primary root using a bar meter. The observational parameters observed in this study were bulk density (annular volumetric), texture (areometer), structure, consistency, plasticity, coefficient of linear extensibility (COLE), the water content of field capacity (gravimetric), and water content of permanent wilting point (compression plate device). , width and depth of soil cracks (cm), plant height (cm), dry weight of plants (g) and length of plant roots (cm).

## 3. RESULT AND DISCUSSION

The results of the analysis of the physical soil properties (see Table 1) show that the COLE value of Vertisols soil from Jeneponto is 0.24, which means that this soil has a high soil swelling and shrinking capacity. The ripple rate of COLE > 0.06 is a critical limit for unstable floors (Fanning & Fanning, 1989).

Table 1. The results of the analysis of the physical properties of the soil before treatment

| No | Physical soil properties of Vertisols | Value |
|---|---|---|
| 1) | Bulk density (g $cm^{-3}$) | 1.30 |
| 2) | Texture | Clay |
| | • sand (%) | 5 |
| | • silt (%) | 13 |
| | • clay (%) | 82 |
| 3) | Soil structure | Prismatic |
| 4) | Consistency (wet) | sticky |
| 5) | COLE value | 0.24 |
| | • swelling (%) | 46.67 |
| | • shrinking (%) | 21.21 |
| 6) | Water content | |
| | • field capacity (%) | 40.80 |
| | • wilting point (%) | 16.20 |
| | • available water (%) | 24.60 |

Table 1 shows that the Vertisols soil sample in this study is dominant clay content of 82% and a high COLE of 0.24. As determined by Hardjowigeno (2003), a COLE value > 0.09 (high) indicates that the soil is sweelling and shrinking. This is because Vertisol soils are dominated by clay fractions, meaning these soils have a fine fraction size. In other words, they have a large number of small size particles and a larger surface area per unit weight of soil, so the particles per unit volume of soil become progressively denser, followed by the magnitude of the bulk density value. This is consistent with Hanafiah's (2010) statement that the smaller the fraction size, the greater the number and the greater the surface area per unit soil weight, meaning that the more micropores are formed. The COLE values and high proportion of clay promote a more extensive swelling process in the soil, resulting in finer lumps in the crushing process. According to Fanning and Fanning (1989), the COLE value of > 0.061 shows a strong shrinkage. Furthermore, according to Sunarminto and Santosa (2008), the mode of shrinkage of montmorillonite clay is the cause of the formation of smooth faces and gilgai microreliefs (cauliflower structure), as well as the process of pedoturbation on Vertisols. The influence of the technical water treatment on the bottom of the Vertisol can be observed in the depth and width of these cracks in the ground. Figures 2 and 3 show a significant difference between the soil water at the surface and the water given in drops. Observations are made simultaneously after three days' watering treatments.

M1A1 M1A2 M1A3 M1A4

Fig 2. Vertisols condition on surface watering treatment (M1)

M2A1 M2A2 M2A3 M2A4

Fig 3. Soil surface condition Vertisols on drip treatment (M2)

Based on Figures 2 and 3, the soil cracking occurs only in surface water irrigation treatment (M1); The 100% FC treatment shows that cracks appear somewhat enormously and reduces the given amount of water (75%, 50% and 25% FC) as little as the width of the cracks appearing on the surface. Meanwhile, in the drip treatment (M2), the soil conditions in the 100%, 75%, 50% and 25% FC treatments have the same soil conditions. Namely, it remains in a moist and loose state, so there are no cracks/fractures on the soil surface. In Table 2, the treatment of direct water application on the surface with a 50% FC wet level (M1A3) and a 25% FC wet level (M1A4) on the second day after casting showed cracks. The treatment with a water content of 100% FC (M1A1) and a water content of 75% FC (M1A2) cracked on the third day after casting. The average cracking of the Vertisols is found in the treatment of irrigation water at the surface with a water content of 100% FC (M1A1), shows the highest value of bottom cracks with a crack width of > 0.18 cm and a depth of > 1.30 cm. In contrast, the treatment with a water content of 25% FC (M1A4) showed the lowest soil crack value with a width of < 0.13 cm and a depth of < 1.00 cm. Examination of treatment interactions with plants showed that the interplay between watering and different moisture water levels had a noticeable effect on increasing plant height. The observation of the corn crop height was carried out for nine weeks. The results of the small real world difference test can be found in Table 4.

Table 2. Vertisols soil crack width

| Treatment | Date of observation | | | | | | |
|---|---|---|---|---|---|---|---|
| | 25-Sep*) | 26-Sep | 27-Sep | 28-Sep*) | 29-Sep | 30-Sep | 01-Oct*) |
| | cm | | | | | | |
| M1A1 | - | - | - | 0.18 | - | - | 0.20 |
| M1A2 | - | - | - | 0.18 | - | - | 0.18 |
| M1A3 | - | - | 0.01 | 0.15 | - | 0.03 | 0.12 |
| M1A4 | - | - | 0.11 | 0.13 | - | 0.07 | 0.12 |

Note: *) watering day and "-" = no cracks occurred

Table 3. Vertisols soil crack depth

| Treatment | Date of observation | | | | | | |
|---|---|---|---|---|---|---|---|
| | 25-Sep*) | 26-Sep | 27-Sep | 28-Sep*) | 29-Sep | 30-Sep | 01-Oct*) |
| | cm | | | | | | |
| M1A1 | - | - | - | 1.30 | - | - | 1.23 |
| M1A2 | - | - | - | 1.40 | - | - | 1.33 |
| M1A3 | - | - | 0.06 | 1.07 | - | 0.23 | 0.90 |
| M1A4 | - | - | 0.73 | 1.00 | - | 0.37 | 0.93 |

Description: *) watering day and "-" = no cracks occurred

Table 4. Maize height (cm)

| Irrigation way | Water content | | | |
|---|---|---|---|---|
| | A1 | A2 | A3 | A4 |
| | | cm | | |
| M1 | 122.70$^{bc}$ | 108.50$^{abc}$ | 96.20$^{a}$ | 102.30$^{a}$ |
| M2 | 101.57$^{a}$ | 125.23$^{c}$ | 109.03$^{abc}$ | 105.67$^{ab}$ |
| BNT 0.0518 | | | | |

Note: The numbers followed by the same letter (a,b,c) mean no significant difference in the BNT0.05 level test

Table 4 shows data that there was a significant difference of plant height between the treatment of water irrigation on the surface (M1). The water content of 100% FC (A1) showed significantly different plant height in the treatment of water contents of 50% FC (A3) and 25% FC (A4) and was not appreciably different from the treatment of 75% FC (A2) ); a water content of 75% FC indicates that the plant height is not optimal, a water content of 50% FC and a water content of 25% FC indicate that the plant height has started to be disturbed. In the drip water treatment (M2), the maximum plant height was reached at a water content of 75% FC (A2) and differed significantly from the water content treatment with 100% FC (A1) and 25% FC (A4) and did not differ significantly from the water content of 50% FC (A3). The drip treatment with a water content of 75% FC (M2A2) showed the highest growth height of 125.2 cm. Meanwhile, the treatment of surface-based water with a volume of 100% FC (M1A1) showed a maximum plant height value of 122.70 cm, but it was not significantly different from the water content of 75% FC in the drip treatment. The distinction between watering and different moisture levels has a noticeable effect on increasing the dry weight of the plant. The dry weight of the plant is observed after harvest. The results of the smallest significance difference test are shown in Table 5.

Table 5. A dry weight of maize (g)

| Irrigation way | Water content | | | |
|---|---|---|---|---|
| | A1 | A2 | A3 | A4 |
| | | g | | |
| M1 | 63.07$^{c}$ | 43.$^{ab}$ | 29.67$^{a}$ | 33.33$^{a}$ |
| M2 | 31.93$^{a}$ | 54.80$^{bc}$ | 39.67$^{a}$ | 38.47$^{a}$ |
| BNT 0.0514 | | | | |

Note: The numbers followed by the same letter (a,b,c) mean no significant difference in the BNT0.05 level test

In Table 5 it can be seen that there is a significant difference between the treatments. For surface water treatment (M1), the water content of 100% FC (A1) indicates the maximum dry weight and differs significantly from other water content treatments (A2, A3 and A4) which have less than optimal dry weight. However, the maximum dry weight when surface treated with 100% FC (M1A1) does not differ appreciably from the bead treated with 75% FC (M2A2). The treatment of surface water with a dampening water content of 100% FC (M1A1) and a drip treatment with a water content of 75% FC (M2A2) showed the results of the BNT test with a value of 0.05, which does not differ significantly. The optimum dry weight value when providing a minimum volume of water, indicated by treatment in drops with a water content of 75% FC (M2A2), is 54.8 g. Meanwhile, the surface irrigation treatment with water content of 50% FC (M1A3) showed the lowest dry weight value of 29.7 g. The amount of water released by dripping is less than on a surface. The results of the analysis showed that the interaction between water release and different moisture levels significantly affected the length of the plant roots. Plant root length data are presented in Table 6.

Table 6. Plant root length

| Irrigation | Water content | | | |
|---|---|---|---|---|
| | A1 | A2 | A3 | A4 |
| | cm | | | |
| M1 | $107.10^{abc}$ | $95.30^{ab}$ | $93.53^{ab}$ | $91.20^{ab}$ |
| M2 | $87.27^{a}$ | $80.10^{a}$ | $116.27^{bc}$ | $124.20^{c}$ |
| BNT 0.0527 | | | | |

Note: The numbers followed by the same letter (a,b,c) mean no significant difference in the BNT level test of 0.05

Based on the data in Table 6, there is a significance difference between the treatments. In surface water irrigation treatment (M1), the water content of 100% FC (A1) indicates the optimal root length, the water content of 75% FC (A2), 50% FC (A3) and 25% FC (A4) indicates that the root length is not optimal. In the drip treatment (M2), the water content of 100% FK (A1) and water content of 75% FK (A2) indicate that the root length is disturbed, but water content of 50% FK (A3) and the dampening water content of 75 % FC (A4) indicates the optimal root length. Treatment of dripping water with a volume of 25% FC (M2A4) showed the highest root length value while providing a minimum water volume, which is 124.2 cm. While treating water in drops with a volume of 75% FC (M2A2) showed the lowest root length value of 80.1 cm. For the maximum root ratio achieved when irrigated in drops with water content of 25% of the volume capacity.

Vertisols use will be optimal if followed by water management. In the findings of observations (Figure 2 and Table 3), soil cracking occurs only in surface water treatment (M1). At the treatment of drip water (M2), the soil remains in a loose and moist. The average crack in the treatment of water content of 100% FC (A1) and 75% FC (A2) occurs every three days after watering, the water content of 50% FC (A3) and the water content of 25% FC (A4) occurs every two days after watering. However, a different approach of giving water will affect the shrinking of Vertisols. Giving water in drops is better than giving water on the surface. In these conditions, giving water causes the soil to be easily flooded, so slowly, the water begins to fill the soil pores, and the clay minerals exposed to water expand. However, after the evapotranspiration process, that soil conditions were easier/faster to dry and crack on the surface. In contrast to drip treatment, the condition of the soil is shown to remain moist at the surface, presumably because the minerals in the soil remain moist and do not undergo shrinkage, resulting in no surface cracks. Sunarminto and Santosa (2008) stated that the higher the COLE in the soil, the more water application with intermittent time would cause the frequency of the shrinkage process to become more significant. Cracks in the soil are caused by the high content of clay fractions and the type of clay minerals that Vertisols possess. As a result of these cracks, soil is exchanged between the surface and the subsurface of the soil. According to Hardjowigeno (2003), the high clay content in vertisols can come from the soil parent material (limestone, sea clay deposits) or from the weathering of the parent material (e.g. from basalt rock). Furthermore, according to Munir (1996), cracks in vertisols occur during the dry season due to the constriction of clay minerals 2:1.

In the results of plant height and plant dry weight observations, surface-based water treatment does not differ significantly from the treatment of water given by drips. However, the treatment with drops with a water content of 75% FC (M2A2) has a higher dry weight than others when viewed from the given amount of water, while the results compared to the treatment with direct water on the surface are not shown differently in the water content of 100% FC (M1A1). In contrast, the lowest dry weight in surface water treatment was achieved with a water content of 50% FC (M1R3).

Providing water content according to the field capacity does not guarantee the production of good plant growth. From the results of Table 5 and Table 6, it can be seen that the treatment of dripping water with a water content of 75% FC (M2A2) is better than that of 100% FC water content (M2A1). This fact occurs at the treatment conditions of 75% FC (A2) where the water availability can affect the activity of nutrient absorption by plant roots so that it affects the increase in plant growth. According to Minardi (2002), water availability directly or indirectly influences almost every metabolic process in plants.

The low productivity in the treatment of surface water with a content of 50% FC (M1R3) is attributed to the fact that the condition of the Vertisols soil is dominated by micropores that are almost filled with water, so that the air in the soil is reduced. According to Jasminarni (2008), when the amount of water in the growing medium is too large, the growing medium becomes anaerobic; conditions like these affect growth because they affect the photosynthesis and metabolic processes of the plants. From the results of the observations of the length of the roots of the plant, it was found that the difference in the treatment mean was very significant. The maximum root length is when treating dripping water (M2) with a water content of 25% FC (A4). This is related to the resilience of plants in times of water scarcity. It is believed that during times of water scarcity, the plant extends its roots to that part of the soil where there is sufficient water for the plant to survive. Plants suffering from water scarcity can maximally absorb the water with increasing extent and depth of the root system (Ai & Patricia, 2013). An efficient root system increases the transport rate and the amount of water transported to the canopy, reduces water loss through the epidermis, and reduces heat absorption from leaf rolling or folding (Supijatno, 2012). Inversely proportional to the length of the roots when treating surface treatments (M1), a water content of 25% FC (A4) indicates the minimum root length. The dense structure of the soil inhibits the deeper penetration of the roots. Since the dense soil makes it difficult for the roots to penetrate, the root extension area is becoming shorter and shorter.

## 4. CONCLUSION

Gradual or continuous irrigation of water in limited quantities (75% of field capacity) can reduce the occurrence of cracks and increase the vegetative growth and root of maize compared to watering treatments on the surface. The way and amount of water applied affects the level and depth of cracks, vegetative growth, and rooting of maize on Vertisols. Therefore, gradual or continuous irrigation of water in limited quantities (75% of field capacity) is more effective and efficient.

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