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SOIL MOISTURE 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 factorial 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 moisture content of 100%, 75%, 50%, and 25% of the field capacity. The results showed that the Vertisols Jeneponto had an available moisture content of 24.60% (field capacity moisture 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 moisture 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: Vertisols, water content, swelling, shrinking

INTRODUCTION

Plants need soil management, including water supply, and will affect soil properties, especially those related to soil density, holding water, and groundwater resistance. One type of soil that needs improvement in its utilization is the Vertisols soil type. Vertisols is a type of soil with relatively high clay content and generally consists of a 2:1 clay mineral predominantly smectitic mineralogy with a high water holding capacity but also with a high water resistance available to plants. The low water available to plants, especially in relatively dry areas, causes water-deficient plants to be unable to grow optimally. Soil Survey Staff (2014); Prasetyo (2007); Wubetu (2017) characterizes Vertisols as a type of soil that is dark gray to blackish, has a clay texture > 30%, has slickened sides; and fracturing that can periodically open and close with a clay mineral composition dominated by clay minerals of type 2: 1. Deep and wide cracks characterize them and have gilgai microrelief with frequent micro knolls and micro-depressions (Wubetu, 2017). These soils have characteristic cyclic pedons, which make them different from other soils. Vertisols are soil whose utilization prospects are pretty good based on their chemical properties, but the obstacle is in terms of soil management which is relatively quite tricky due to the influence of the physical properties of these Vertisols. Based on the results of field surveys, in dry conditions, the soil is hard, and experiences cracks on the soil surface 1 cm wide and at a depth of 10 to 50 cm. This condition became a severe constraint to the farmers in the cultivation of crops because it affected crop productivity. Cracks problems occur due to the lack of water availability which affects the physical properties of Vertisols. According to Mukanda and Mapiki (2001), the problem of the physical properties of this soil is in the form of heavy clay texture, swelling and shrinking properties, low infiltration speed, and slow water drainage. Other constraints on Vertisols from environmental factors, namely naturally limited water availability and heavy soil management. The type of clay mineral montmorillonite influences these constraints. The negative impact of montmorillonite shrinking on agricultural cultivation is that if the cracks are wide, they will break the root tissue for annuals (Sunarminto & Santosa, 2008). Vertisols soil management needs to keep cracks to a minimum by regulating the water supply. According to Jasminarni (2008), the need for water by plants is measured based on the percentage of field capacity. Furthermore, from the results of Suwarto's research (2003), it was reported that the highest maize growth yield was in the treatment of field capacity soil conditions. This soil requires excellent and proper water management to be suitable for plant growth.

MATERIALS AND METHODS

This research is trial research conducted at the greenhouse of the Faculty of Agriculture, Hasanuddin University, Makassar, Indonesia. Soil samples were obtained from Bangkala District, Jeneponto Regency, South Sulawesi Province, Indonesia (location shown in Figure 1) compositely from a depth of 60 cm, which was then put into a pot experiment. The study used a factorial design with two factors, namely the factor of giving water as many as 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 combination of treatments there were eight, and each combination of treatments was repeated three times so that 24 experimental pots were obtained. The soil that has been taken is compositely cleaned of rocks or the roots of the carried plants. Then mash and then put in a pot of 10 kg. A portion of the soil is taken for the analysis of physical properties. The soil that has been put in a pot and then planted with maize seeds 5 cm deep, as much as 2 seeds per pot. For the treatment of drops, previously, an infusion device has been paired with a difference in drip time adjusted to the treatment. The fertilizer is applied three days after planting with a dose of N fertilizer of 300 kg ha^{-1}. Fertilizer is immersed into the soil 5 cm deep in a circle with a distance of 5 cm from the seeds and then re-covered with soil.

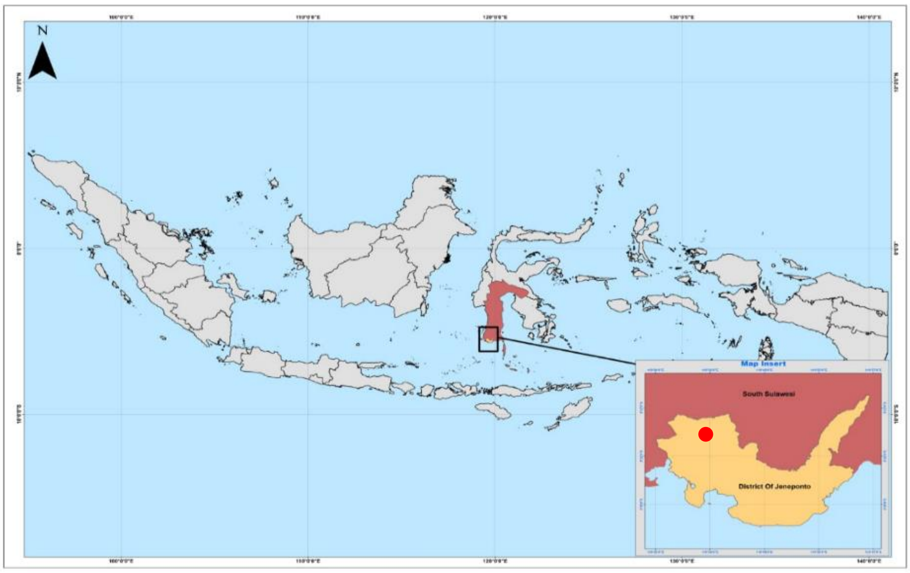

Fig 1. Vertisols soil sampling location (red dot)

Watering is carried out to regulate the moisture content of the growing medium following the treatment. The moisture content in the planting medium is sought to remain constant during observation. For the treatment of watering water on the surface, the application of water according to the treatment continues every three days after watering (according to the preliminary observations that have been made where cracks in the soil begin to occur on the third day after watering). For drip treatment, water is given daily until it reaches the moisture content according to the treatment while still adjusting the time limit from the initial observation—determination of moisture content in the treatment based on the percentage of field capacity. Gravimetric methods carry out the determination of field capacity. The separation of water by heating is commonly called the gravimetric method and is a method of measuring directly (Topp & Ferre, 2002). The gravimetric method is the simplest conceptually in determining the moisture content of the soil. Observations include measurements of plant height carried out once a week and observations of cracks on the soil surface carried out before watering. The height of maize was measured starting from the lower base stems (border with the soil surface) to the tip of the top leaf. Harvesting is carried out upon reaching the flowering phase at 64 DAP (the day after planting). After harvesting, the roots of the plant were cleaned of the soil that is still attached before measuring the length of the roots. The length of the roots was measured in a fresh and clean state of the soil. Measurements are not made on the root hairs. Measurement of root length was carried out according to the root structure in the root system according to the classification of Rao and Ito (1998), which consists of the main root (*tap root*), primary root, secondary *root*, and tertiary root. In this experiment, root length was measured by measuring the length of the primary root only using a bar meter. The observation parameters observed in this study were bulk density (ring volumetric), texture (hydrometer), structure, consistency, plasticity, coefficient of linear extensibility (COLE) value, the water content of field capacity (gravimetric), and water content of permanent wilting point (pressure plate apparatus), width and depth of soil cracks (cm), plant height (cm), dry weight of plants (g) and length of plant roots (cm).

RESULT AND DISCUSSION

The results of the analysis of soil physical properties (see Table 1) show that the COLE value of Vertisols soil from Jeneponto is worth 0.24, which means that this soil has a high soil swelling shrinking power. The corrugation rate of COLE > 0.06 is a critical limit for unstable soils (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)	Plasticity 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 dark in color with a dominating clay fraction of 82% and a high COLE value of 0.24. As per the determination of Hardjowigeno (2003), the COLE value > 0.09 (high) indicates that the soil expands and shrivels markedly, and the content of montmorillonite is high. This is because vertisols soils are dominated by clay fractions which means that these soils have a fine fraction size. In other words, they have a large number of particles and a wider surface area per unit weight of the soil so that the particles per unit volume of the soil are increasingly denser, followed by the magnitude of the bulk density value. This is according to the statement of Hanafiah (2010) that the smaller the fraction size, the more the number and the more surface area per unit of soil weight, which means that the more micropore size is formed.

The COLE values and high clay fraction levels will encourage a more extensive swelling process of soil so that in the crushing process, it will produce finer-sized lumps. According to Fanning and Fanning (1989), the COLE value of > 0.061 soils has a severe level of shrinkage. Furthermore, according to Sunarminto and Santosa (2008), the nature of the shrinkage from montmorillonite clay is the cause of the formation of slickened sides and gilgai microrelief (cauliflower structure), as well as the process of pedoturbation on Vertisols. The influence of technical treatment of water giving on the soil of Vertisols can be observed from the depth and width of these soil cracks. Figures 2 and 3 show a significant difference between the soil water on the surface and that given water in drops. Observations are carried out simultaneously after three days of water-giving treatments.

M1A1 M1A2 M1A3 M1A4

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

M1A1 M1A2 M1A3 M1A4

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

Based on Figures 2 and 3, the soil cracks only occur on the surface water watering treatment (M1); the treatment of 100% FC cracks occur somewhat enormously and decreases the amount of water given (75%, 50%, and 25% of FC) as small as the width of the cracks that occur on the surface. Meanwhile, in the drip treatment (M2), the soil condition at the treatment of 100%, 75%, 50%, and 25% of FC has the same soil conditions. Namely, it remains in a moist and loose state so that there are no cracks/fracturing on the soil surface. In Table 2, the treatment of direct water application on the surface with a moisture content of 50% FC (M1A3) and a moisture content of 25% FC (M1A4) experienced cracks on the second day after watering. The treatment of moisture content of 100% FC (M1A1) and moisture content of 75% FC (M1A2) experienced cracks on the third day after watering. While in the drip treatment, the surface on the ground does not experience cracks. The soil Vertisols' average cracking can be seen in the treatment of watering water on the surface with a moisture content of 100% FC (M1A1), shows the highest value of soil cracks with a crack width_of > 0.18 cm and a depth of > 1.30 cm. Meanwhile, the treatment with a moisture 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. The analysis of treatment interactions with plants showed that the interaction between water feeding and different moisture content had a noticeable effect in increasing plant height. Observation of maize crop height was carried out for nine weeks. The results of the minor real difference test can be seen 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			
M_1A_1	-	-	-	0,18	-	-	0,20
M_1A_2	-	-	-	0,18	-	-	0,18
M_1A_3	-	-	0,01	0,15	-	0,03	0,12
M_1A_4	-	-	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			
M_1A_1	-	-	-	1,30	-	-	1,23
M_1A_2	-	-	-	1,40	-	-	1,33
M_1A_3	-	-	0,06	1,07	-	0,23	0,90
M_1A_4	-	-	0,73	1,00	-	0,37	0,93

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

Table 4. Maize height (cm)

Water giving	Water content			
	A_1	A_2	A_3	A_4
		cm		
M_1	$122,70^{bc}$	$108,50^{abc}$	$96,20^{a}$	$102,30^{a}$
M_2	$101,57^{a}$	$125,23^{c}$	$109,03^{abc}$	105.67^{from}
BNT 0,0518,39				

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

Table 5 shows data that there was a significant difference between the treatment of water watering on the surface (M_1). The water content of 100% FC (A_1) showed a markedly different plant height with the treatment of water content of 50% FC (A_3) and 25% FC (A_4) and did not differ markedly from the treatment of 75% FC(A_2)); water content of 75% FC indicates that the plant height is less than optimum, the water content of 50% FC and the water content of 25% FC indicate that the plant height has begun to be disturbed. In the drip water treatment (M_2), the maximum plant height was obtained at a moisture content of 75% FC (A_2) and differed markedly from the treatment of water content of 100% FC (A_1) and 25% FC (A_4) and did not differ markedly from the water

content of 50% FC (A3). At a moisture content of 50% FC and a moisture content of 25% FC, the plant height is in a less-than-optimum state. The treatment of water in drops with a moisture content of 75% FC (M2A2) showed the highest plant height value, 125.2 cm. Meanwhile, the treatment of water on a surface basis with a volume of 100% FC (M1A1) showed a maximum plant height value of 122.70 cm, but it did not differ markedly from the moisture content of 75% FC in the drip treatment. The distinction between the giving of water and different moisture content has a noticeable effect in increasing the dry weight of the plant. Observation of the dry weight of the plant is carried out after harvest. The results of the minor real difference test can be seen in Table 5.

Table 5. A dry weight of maize (g)

Water giving	Water content			
	A1	A2	A3	A4
		g		
M1	63,07[c]	43.67[from]	29,67[a]	33,33[a]
M2	31,93[a]	54,80[bc]	39,67[a]	38,47[a]
BNT 0,0514,11				

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 fundamental difference between the treatment given. In the surface water treatment (M1), the moisture content of 100% FC (A1) indicates the maximum dry weight and differs markedly from other water content treatments (A2, A3, and A4), which show a less than optimum dry weight. Nevertheless, the maximum dry weight on surface treatment with 100% FC (M1A1) does not differ markedly from the treatment in drops with 75% FC (M2A2). The treatment of surface water with a moisture content of 100% FC (M1A1) and drip treatment with a water content of 75% FC (M2A2) showed the results of the BNT test with a level of 0.05, which did not differ markedly. The optimum dry weight value with the provision of a minimum volume of water, indicated by the treatment in drops with a moisture content of 75% FC (M2A2), which is 54.8 g. Meanwhile, the surface watering treatment with a moisture content of 50% FC (M1A3) showed the lowest dry weight value of 29.7 g. The amount of water given by drops is less than on a surface basis. The results of the fingerprint analysis showed that the interaction between water giving and different moisture content significantly affected the length of plant roots. Data on the length of plant roots are shown in Table 6.

Table 6. Plant root length

Water feeding	Water content			
	A1	A2	A3	A4
		cm		
M1	107,10[abc]	95.30[from]	93.53[from]	91.20[from]
M2	87,27[a]	80,10[a]	116,27[bc]	124,20[c]
BNT 0,0527,54				

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 noticeable difference between the treatments given. In the surface water watering treatment (M1), the moisture content of 100% FC (A1) indicates the optimum root length, the moisture content of 75% FC (A2), the moisture content of 50% FC (A3), and the water content of 25% FC (A4) indicates the root length is less than optimal. At the drip water treatment (M2), the moisture content of 100% FC (A1) and the moisture content of 75% FC (A2) indicate that the root length is disturbed, but the moisture content of 50% FC (A3) and the moisture content of 75% FC (A4) indicate the optimum root length. The treatment of drip water with a volume of 25% FC (M2A4) showed the highest root length value with the provision of a minimum volume of water, which is 124.2 cm. While the treatment of water in drops with a volume of 75% FC (M2A2) showed the lowest root length value of 80.1 cm. For the maximum ratio of roots obtained at administration in drops with a moisture content of 25% of the roomy capacity.

Vertisols soil use will be optimal if followed by water feeding. In the results 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 state. The average crack in the administration of water content of 100% FC (A1) and water content of 75% FC (A2) occurs every three days after watering, while in the administration, the moisture content of 50% FC (A3) and the moisture content of 25% FC (A4) occurs every two days after watering. Vertisols having high montmorillonite clay will make the soil effortlessly float during watering. However, a different way of giving water will affect the shrinking of these 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, there was a drastic dehumidifier, allegedly due to the shrinkage of type 2: 1 clay minerals by Vertisols, so that soil conditions were easier/faster to dry and crack on the surface.

In contrast to the drip treatment, it shows that the condition of the soil on the surface remains in a moist state, presumably because the minerals in the soil remain wet and do not experience shrinking so that there are no cracks on the surface. Sunarminto and Santosa (2008) stated that the higher the COLE value in the soil, the more water application with intermittent time would cause the frequency of the shrinking process to be more significant. Cracks in the soil occur due to the high content of clay fractions and the type of clay minerals possessed by Vertisols. As a result of these cracks, soil will be exchanged between the surface and sub-surface of the soil. According to Hardjowigeno (2003), the high clay content in Vertisols can come from soil parent material (limestone, sea clay deposits) or the result of weathering of the parent material (e.g., from basalt rock). Furthermore, according to Munir (1996), cracks in Vertisols occur in the dry season due to the constriction of clay minerals 2: 1.

In the results of observations of plant height and dry weight of plants, water treatment on a surface basis is not significantly different from the treatment of water given by drops. However, when viewed from the volume of water given, the treatment by drops with a moisture content of 75% FC (M2A2) has a higher dry weight than others, while when compared to the treatment of direct water on the surface the results are not different shown in the water content of 100% FC (M1A1). In contrast, the lowest dry weight was obtained in surface water treatment with a moisture content of 50% FC (M1R3). The

provision of moisture content according to field capacity does not guarantee the production of good plant growth. From the results of Table 5 and Table 6, the treatment of drip water with a moisture content of 75% FC (M2A2) is better than the water content of 100% FC (M2A1). This fact occurs in the treatment conditions of 75% FC (A2), where 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 affects almost every metabolic process of plants. The low productivity in the treatment of surface water with a moisture content of 50% FC (M1R3) is thought to be because the condition of the Vertisols soil is dominated by micropores which are almost filled with water so that the air in the soil is reduced. According to Jasminarni (2008), the planting media becomes anaerobic when the amount of water in the planting media is excessive; conditions like this will harm growth because it interferes with plants' photosynthesis and metabolic processes. On the results of observations of the length of the roots of the plant, the difference in the average value of the treatment was seen to be very significant. The maximum root length is at the treatment of drip water (M2) with a moisture content of 25% FC (A4). This is related to the resistance of plants in times of water shortage. It is suspected that in times of lack of water, the plant extends its roots to the part of the soil with sufficient water availability so the plant can survive. Plants that experience water shortages can take water to the maximum with increased expansion and depth of the root system (Ai & Patricia, 2013). An efficient root system will increase the transport rate and the amount of water transported to the canopy, reduce water loss through the epidermis and reduce heat absorption through leaf rolling or folding (Supijatno, 2012). Inversely proportional to the length of the roots at the treatment of surface administration (M1), a moisture content of 25% FC (A4) indicates the minimum root length. The dense structure of the soil will inhibit the rate of penetration of the roots more deeply. Because the dense soil is difficult to penetrate the roots, the root lengthening area is getting shorter. In soils with a high-density level, the total length of their roots is low. Rusdiana et al. (2000) argue that if the density of the soil increases, then the macro pore space decreases, and root penetration is inhibited.

CONCLUSION

Gradual or continuous provision 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 manner and amount of water applied affects the level and depth of cracks, vegetative growth, and rooting of maize on Vertisols. Therefore, gradual or continuous provision of water in limited quantities (75% of field capacity) is more effective and efficient.

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Dear authors The article written by Neswati et al. gave an interesting overview of the moisture management on the physical chara
However, plenty of sentences are unclear to readers; therefore, sentence paraphrasing and rewriting are highly necessary. Please
impossible to translate Bahasa directly to English without looking into the context, as this may also compromise sentence clarity. I
use a certified English translator to improve the quality of the manuscript before submitting the revision. Please see the attached f
the manuscript. Best regards, ReviewerRecommendation: Revisions Required

SOIL MOISTURE 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 factorial 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 moisture content of 100%, 75%, 50%, and 25% of the field capacity. The results showed that the Vertisols Jeneponto had an available moisture content of 24.60% (field capacity moisture 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 moisture 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: Vertisols, water content, swelling, shrinking

INTRODUCTION

Plants need soil management, including water supply, and will affect soil properties, especially those related to soil density, holding water, and groundwater resistance. One type of soil that needs improvement in its utilization is the Vertisols soil type. Vertisols is a type of soil with relatively high clay content and generally consists of a 2:1 clay mineral predominantly smectitic mineralogy with a high water holding capacity but also with a high water resistance available to plants. The low water available to plants, especially in relatively dry areas, causes water-deficient plants to be unable to grow optimally. Soil Survey Staff (2014); Prasetyo (2007); Wubetu (2017) characterizes Vertisols as a type of soil that is dark gray to blackish, has a clay texture > 30%, has slickened sides; and fracturing that can periodically open and close with a clay mineral composition dominated by clay minerals of type 2: 1. Deep and wide cracks characterize them and have gilgai microrelief with frequent micro knolls and micro-depressions (Wubetu, 2017). These soils have characteristic cyclic pedons, which make them different from other soils. Vertisols are soil whose utilization prospects are pretty good based on their chemical properties, but the obstacle is in terms of soil management which is relatively quite tricky due to the influence of the physical properties of these Vertisols. Based on the results of field surveys, in dry conditions, the soil is hard, and experiences

Commented [M1]: Secara keseluruhan perlu dicek kembali Bahasa Inggrisnya, terutama terkait dengan grammar dan susuan kalimat

Commented [M2]: Rancangan acak lengkap? Apa rancangan acak kelompok?

Commented [M3]: Istilah yang umum dipakai adalah available water content…
Untuk yang field capacity juga edit ya moisture menjadi water

Commented [M4]: Sepertinya bisa dicari istilah yang lebih tepat ya

Commented [M5]: Kalimat ini sedikit membingungkan karena terlalu panjang. Terutama setelah "as well as…..", nah ini ada apa dengan penggunaan air dalam jumlah yang sedikit….jadi sebaiknya ini dipecah menjadi 2 kallimat sehingga penyusunannya dalam Bahasa inggris juga menjadi lebih sistematis.

Commented [M6]: Urut abjad

Commented [M7]: Tujuan dari penelitian belum tersurat dengan jelas di dalam bab ini

Commented [M8]: Perbaikan pemanfaatannya? Atau perbaikan sifat fisik yang mendukung pertumbuhan tanaman?

Commented [M9]: Perlu acuan.

Commented [M10]: Mohon cek kembali literatur apakah memang suatu tanah dikatakan memiliki tekstur klei apabila kandungan klei >30%? Bisa juga diperkaya dari literatur lain di luar 3 literatur yang ditulis di sini

Commented [M11]: Mungkin bisa pakai istilah lain yang lebih tepat, bukan pretty….

cracks on the soil surface with 1 cm wide and at a depth of 10 to 50 cm. This condition became a severe constraint to the farmers in the cultivation of crops because it affected crop productivity. Cracks problems occur due to the lack of water availability which affects the physical properties of Vertisols. According to Mukanda and Mapiki (2001), the problem of the physical properties of this soil is in the form of heavy clay texture, swelling and shrinking properties, low infiltration speed, and slow water drainage. Other constraints on Vertisols from environmental factors, namely naturally limited water availability and heavy soil management. The type of clay mineral montmorillonite influences these constraints. The negative impact of montmorillonite shrinking on agricultural cultivation is that if the cracks are wide, they will break the root tissue for annuals (Sunarminto & Santosa, 2008). Vertisols soil management needs to keep cracks to a minimum by regulating the water supply. According to Jasminarni (2008), the need for water by plants is measured based on the percentage of field capacity. Furthermore, from the results of Suwarto's research (2003), it was reported that the highest maize growth yield was in the treatment of field capacity soil conditions. This soil requires excellent and proper water management to be suitable for plant growth.

Commented [M12]: Speed or rate? Pilih istilah yang lebih tepat ya

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Commented [M13]: Annuals crop? Or ....

Commented [M14]: Susun ulang dan cek grammer ya

Commented [M15]: Field capacity of what? Please write in detail.

MATERIALS AND METHODS

This research is trial research conducted at the greenhouse of the Faculty of Agriculture, Hasanuddin University, Makassar, Indonesia. Soil samples were obtained from Bangkala District, Jeneponto Regency, South Sulawesi Province, Indonesia (location shown in Figure 1) compositely from a depth of 60 cm, which was then put into a pot experiment. The study used a factorial design with two factors, namely the factor of giving water as many as 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 combination of treatments there were eight, and each combination of treatments was repeated three times so that 24 experimental pots were obtained. The soil that has been taken is compositely cleaned of rocks or the roots of the carried plants. Then mash and then put in a pot of 10 kg. A portion of the soil is taken for the analysis of physical properties. The soil that has been put in a pot and then planted with maize seeds 5 cm deep, as much as 2 seeds per pot. For the treatment of drops, previously, an infusion device has been paired with a difference in drip time adjusted to the treatment. The fertilizer is applied three days after planting with a dose of N fertilizer of 300 kg ha^{-1}. Fertilizer is immersed into the soil 5 cm deep in a circle with a distance of 5 cm from the seeds and then re-covered with soil.

Commented [M16]: Perlu diperjelas, apakah rancangan acak lengkap atau rancangan acak kelompok

Commented [M17]: Cek grammer

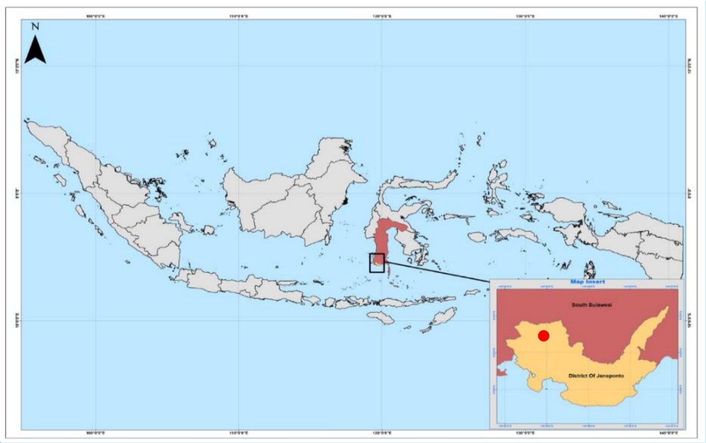

Fig 1. Vertisols soil sampling location (red dot)

Watering is carried out to regulate the moisture content of the growing medium following the treatment. The moisture content in the planting medium is sought to remain constant during observation. For the treatment of watering water on the surface, the application of water according to the treatment continues every three days after watering (according to the preliminary observations that have been made where cracks in the soil begin to occur on the third day after watering). For drip treatment, water is given daily until it reaches the moisture content according to the treatment while still adjusting the time limit from the initial observation—determination of moisture content in the treatment based on the percentage of field capacity. Gravimetric methods carry out the determination of field capacity. The separation of water by heating is commonly called the gravimetric method and is a method of measuring directly (Topp & Ferre, 2002). The gravimetric method is the simplest conceptually in determining the moisture content of the soil. Observations include measurements of plant height carried out once a week and observations of cracks on the soil surface carried out before watering. The height of maize was measured starting from the lower base stems (border with the soil surface) to the tip of the top leaf. Harvesting is carried out upon reaching the flowering phase at 64 DAP (the day after planting). After harvesting, the roots of the plant were cleaned of the soil that is still attached before measuring the length of the roots. The length of the roots was measured in a fresh and clean state of the soil. Measurements are not made on the root hairs. Measurement of root length was carried out according to the root structure in the root system according to the classification of Rao and Ito (1998), which consists of the main root (*tap root*), primary root, secondary *root*, and tertiary root. In this experiment, root length was measured by measuring the length of the primary root only using a bar meter. The observation parameters observed in this study were bulk density (ring volumetric), texture (hydrometer), structure, consistency, plasticity, coefficient of linear extensibility (COLE) value, the water content of field capacity (gravimetric), and water content of permanent wilting point (pressure plate apparatus), width and depth of soil cracks (cm), plant height (cm), dry weight of plants (g) and length of plant roots (cm).

Commented [M18]: Resolusi peta perlu ditingkatkan sehingga koordinat tetap terbaca dengan baik.

Legenda peta juga perlu dilengkapi, karena jika seperti ini seperti peta buta, salah satunya karena pembaca diminta menebak sendiri di mana lokasi sample....

View utama dan insert sepertinya terbalik...umumnya yang lebih detil menjadi view utama

Commented [M19]: Following di sini sepertinya kurang tepat ya..silahkan cari istilah yang lebih tepat ya

Commented [M20]: Cek grammer ya

Nama analisis sebenarnya untuk bisa mengukur KA kapasitas lapang?

Commented [M21]: Parameter observasi umumnya mengacu pada observasi lapangan. Dengan demikian akan lebih baik dibedakan mana parameter observasi lapang, dan mana parameter yang dianalisis di laboratorium

Commented [M22]: Ini apakah maksudnya KA biasa yang menunjukkan bagaimana kondisi di lapang sesungguhya? Bukan KA KL yang ditentukan dengan pressure plate apparatus? Jika memang bukan, lalu mneghitung kadar air tersedia (available water) yang di tabel 1, bagaimana?

RESULT AND DISCUSSION

The results of the analysis of soil physical properties (see Table 1) show that the COLE value of Vertisols soil from Jeneponto is worth 0.24, which means that this soil has a high soil swelling shrinking power. The corrugation rate of COLE > 0.06 is a critical limit for unstable soils (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)	Plasticity 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 dark in color with a dominating clay fraction of 82% and a high COLE value of 0.24. As per the determination of Hardjowigeno (2003), the COLE value > 0.09 (high) indicates that the soil expands and shrivels markedly, and the content of montmorillonite is high. This is because vertisols soils are dominated by clay fractions which means that these soils have a fine fraction size. In other words, they have a large number of particles and a wider surface area per unit weight of the soil so that the particles per unit volume of the soil are increasingly denser, followed by the magnitude of the bulk density value. This is according to the statement of Hanafiah (2010) that the smaller the fraction size, the more the number and the more surface area per unit of soil weight, which means that the more micropore size is formed.

The COLE values and high clay fraction levels will encourage a more extensive swelling process of soil so that in the crushing process, it will produce finer-sized lumps. According to Fanning and Fanning (1989), the COLE value of > 0.061 soils has a severe level of shrinkage. Furthermore, according to Sunarminto and Santosa (2008), the nature of the shrinkage from montmorillonite clay is the cause of the formation of slickened sides and gilgai microrelief (cauliflower structure), as well as the process of pedoturbation on Vertisols. The influence of technical treatment of water giving on the soil of Vertisols can be observed from the depth and width of these soil cracks. Figures 2 and 3 show a significant difference between the soil water on the surface and that given water in drops. Observations are carried out simultaneously after three days of water-giving treatments.

Commented [M23]: Ini angkanya persis seperti ini? Tidak ada desimalnya?

Commented [M24]: Apakah yakin sturktur tanahnya berbentuk prismatik?

Commented [M25]: Tidak ada istilah ini di dalam penetapan plastisitas. Perlu dipastikan dulu kembali, konsistensi basah yang telah ditentukan, apakah menetapkan sifat plastic atau melekat? Jika plastisitas, maka istilah wet sticky itu tidak ada dalam penetapan plastisitas, mohon dicek kembali dan tentukan istilah Bahasa inggrisnya dengan tepat, karena dalam penetapan sifat melekat, juga tidak ada istilah "wet sticky"

Commented [M26]: Belum disebutkan metodenya di bagian metode

Commented [M27]: Belum disebutkan metodenya di bagian metode

Commented [M28]: Di dalam tabel tersebut tidak menunjukkan warna tanah

Commented [M29]: Perlu dilengkapi, "small size particle" or what?

Commented [M30]: Level? Or content? Mana yang lebih tepat?

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Commented [M31]: Apa bener perbedaan ini yang terlihat dari gambar? BUkannya perbedaan permukaan tanah karena kedua perlakuan tersebut?

M1A1 M1A2 M1A3 M1A4

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

M1A1 M1A2 M1A3 M1A4

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

Based on Figures 2 and 3, the soil cracks only occur on the surface water watering treatment (M1); the treatment of 100% FC show that cracks occur somewhat enormously and decreases the amount of water given (75%, 50%, and 25% of FC) as small as the width of the cracks that occur on the surface. Meanwhile, in the drip treatment (M2), the soil condition at the treatment of 100%, 75%, 50%, and 25% of FC has the same soil conditions. Namely, it remains in a moist and loose state so that there are no cracks/fracturing on the soil surface. In Table 2, the treatment of direct water application on the surface with a moisture content of 50% FC (M1A3) and a moisture content of 25% FC (M1A4) experienced cracks on the second day after watering. The treatment of moisture content of 100% FC (M1A1) and moisture content of 75% FC (M1A2) experienced cracks on the third day after watering. While in the drip treatment, the surface on the ground does not experience cracks. The soil Vertisols' average cracking can be seen in the treatment of watering water on the surface with a moisture content of 100% FC (M1A1), shows the highest value of soil cracks with a crack width of > 0.18 cm and a depth of > 1.30 cm. Meanwhile, the treatment with a moisture 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. The analysis of treatment interactions with plants showed that the interaction between water feeding and different moisture content had a noticeable effect in increasing plant height. Observation of maize crop height was carried out for nine weeks. The results of the minor real difference test can be seen in Table 4.

Commented [M32]: M1 apa M2?

Commented [M33]: Susun ulang ya kalimatnya, ini agak susah dipamahi, terutama penggunaan istilah " as small as" di sini

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Commented [M34]: Setelah dua kalimat ini, perlu diberi tambahan penjelasan, misalnya, kenapa KA 100 FC menghasilkan rekahan yang lebih besar dibandingkan saat diberikan KA yang lebih rendah.

Commented [M35]: Ini sebaiknya jadi paragraph terpisah.? Bisa disatukan dengan paragraph di bawah tabel 4,

Dan pada paragraph ini perlu ditambahkan pembahasannya, missal mengapa perbedaan cara pemberian air dan jumlah air yang ditambahkan berpengaruh terhadap peningkatan tinggi tanaman? Perlu juga dibahas terkait cara M2, kenapa tinggi tanaman yang A2 lebih tinggi dibandingkan A1? Karena apa yang disampaikan pada pargraf ini baru sebatas menerangkan isi tabel saja, belum ada pembahasannya

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)

Water giving	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^{from}
BNT 0,0518,39				

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

Table 5 shows data that there was a significant difference between the treatment of water watering on the surface (M1). The water content of 100% FC (A1) showed a markedly different plant height with the treatment of water content of 50% FC (A3) and 25% FC (A4) and did not differ markedly from the treatment of 75% FC(A2)); water content of 75% FC indicates that the plant height is less than optimum, the water content of 50% FC and the water content of 25% FC indicate that the plant height has begun to be disturbed. In the drip water treatment (M2), the maximum plant height was obtained at a moisture content of 75% FC (A2) and differed markedly from the treatment of water content of 100% FC (A1) and 25% FC (A4) and did not differ markedly from the water

Commented [M36]: Judul tabel perlu dilengkapi dengan perlakuan mana

Commented [M37]: Sama seperti komentar di atas

Table 3 belum diacu di dalam text

Commented [M38]: Titik2 di sini seharusnya tidak sampai pada kolom "water giving"

Commented [M39]: Belum ada keterangan ini di bawah tabel? Apa mungkin ini salah ketik? Cek kesesuaiannya dengan penjelasan pada paragraph di bawahnya

Commented [M40]: Keternagan ini masih kurang,...angka diikuti hurus sama, angka yang mana? Pada kolom atau baris?

Commented [M41]: Tabel 4 apa 5?

Commented [M42]: Antara M1 dengan apa? Kalimat ini sepertinya belum selesai

Commented [M43]: Mungkin akan lebih baik jika dilengkapi seperti ini: pemberian kadar air 75% mengindikasikan.....

Karena akan kurang tepat jika hanya: KA 75% mengindikasikan tinggi tanaman....seperti ada yang kurang...cek kalimat yang lain ya

Commented [M44]: Dari mana menyimpulkan bahwa pada KA ini pertumbuhan tinggi tanaman paling optmum? Apa ada literatur pendukung? Perlu ditambahkan ya

Commented [M45]: Kalimat ini terlalu panjang, pecah menjadi dua kalimat

content of 50% FC (A3). At a moisture content of 50% FC and a moisture content of 25% FC, the plant height is in a less-than-optimum state. The treatment of water in drops with a moisture content of 75% FC (M2A2) showed the highest plant height value, 125.2 cm. Meanwhile, the treatment of water on a surface basis with a volume of 100% FC (M1A1) showed a maximum plant height value of 122.70 cm, but it did not differ markedly from the moisture content of 75% FC in the drip treatment. The distinction between the giving of water and different moisture content has a noticeable effect in increasing the dry weight of the plant. Observation of the dry weight of the plant is carried out after harvest. The results of the minor real difference test can be seen in Table 5.

Table 5. A dry weight of maize (g)

Water giving	Water content			
	A1	A2	A3	A4
		g		
M1	63,07[c]	43.67[from]	29,67[a]	33,33[a]
M2	31,93[a]	54,80[bc]	39,67[a]	38,47[a]
BNT 0,0514,11				

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 fundamental difference between the treatment given. In the surface water treatment (M1), the moisture content of 100% FC (A1) indicates the maximum dry weight and differs markedly from other water content treatments (A2, A3, and A4), which show a less than optimum dry weight. Nevertheless, the maximum dry weight on surface treatment with 100% FC (M1A1) does not differ markedly from the treatment in drops with 75% FC (M2A2). The treatment of surface water with a moisture content of 100% FC (M1A1) and drip treatment with a water content of 75% FC (M2A2) showed the results of the BNT test with a level of 0.05, which did not differ markedly. The optimum dry weight value with the provision of a minimum volume of water, indicated by the treatment in drops with a moisture content of 75% FC (M2A2), which is 54.8 g. Meanwhile, the surface watering treatment with a moisture content of 50% FC (M1A3) showed the lowest dry weight value of 29.7 g. The amount of water given by drops is less than on a surface basis. The results of the fingerprint analysis showed that the interaction between water giving and different moisture content significantly affected the length of plant roots. Data on the length of plant roots are shown in Table 6.

Table 6. Plant root length

Water feeding	Water content			
	A1	A2	A3	A4
		cm		
M1	107,10[abc]	95.30[from]	93.53[from]	91.20[from]
M2	87,27[a]	80,10[a]	116,27[bc]	124,20[c]
BNT 0,0527,54				

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

Commented [M46]: Darimana menyatakan ini kurang dari optimum? Perlu acuan literatur lain untuk menguatkan pernyataan yang ditulis.

Commented [M47]: Perlu ditambah penjelasan, kenapa hal ini terjadi

Commented [M48]: Ini sebaiknya paragraph terpisah karena sudah membahas parameter yang berbeda, bisa disatukan dengan paragraph di bawah tabel 5.

Commented [M49]: Paragraph di bawah tabel 5 baru sebatas menerangkan isi tabel, belum ada penjelasan missal kenapa perlakuan M1A1 menyebabkan bobot kering paling tinggi?

Commented [M50]: Ini from?

Sedangkan di bawah tabel tidak ada keterangan terkait ini. Apa mungkin ada kesalahan ketik?

Karena dari penjelasan pada paragraph di atasnya dikatakan A1 tidak berbeda nyata dengan A2.

Commented [M51]: Nilai optimumnya yang mana?

Commented [M52]: Sepertinya kedua kalimat ini memiliki makna yang sama ya? Jika memang ya, bisa pilih salah satu saja ya, biar ga double

Commented [M53]: Bagaimana menentukan bahwa nilai ini yang optimum? Karena biasanya jika dikatakan optimum, itu perlu dibandingkan dengan suatu literatur tertentu yang memang penelitian terkait pertumbuhan optimum dari Jagung.

Jika nilai hanya dibandingkan antara 1 perlakuan dengan lainnya, mungkin lebih tepat dikatakan paling maksimum ya dari penelitian ini?

Commented [M54]: Kenapa jumlah air metode tetes < metode permukaan? Bukannya di metode disebutkan jumlah airnya sama?

Commented [M55]: Ini jadikan paragraph baru ya

Based on the data in Table 6, there is a noticeable difference between the treatments given. In the surface water watering treatment (M1), the moisture content of 100% FC (A1) indicates the optimum root length, the moisture content of 75% FC (A2), the moisture content of 50% FC (A3), and the water content of 25% FC (A4) indicates the root length is less than optimal. At the drip water treatment (M2), the moisture content of 100% FC (A1) and the moisture content of 75% FC (A2) indicate that the root length is disturbed, but the moisture content of 50% FC (A3) and the moisture content of 75% FC (A4) indicate the optimum root length. The treatment of drip water with a volume of 25% FC (M2A4) showed the highest root length value with the provision of a minimum volume of water, which is 124.2 cm. While the treatment of water in drops with a volume of 75% FC (M2A2) showed the lowest root length value of 80.1 cm. For the maximum ratio of roots obtained at administration in drops with a moisture content of 25% of the roomy capacity.

Vertisols soil use will be optimal if followed by water feeding. In the results 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 state. The average crack in the administration of water content of 100% FC (A1) and water content of 75% FC (A2) occurs every three days after watering, while in the administration, the moisture content of 50% FC (A3) and the moisture content of 25% FC (A4) occurs every two days after watering. Vertisols having high montmorillonite clay will make the soil effortlessly float during watering. However, a different way of giving water will affect the shrinking of these 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, there was a drastic dehumidifier, allegedly due to the shrinkage of type 2: 1 clay minerals by Vertisols, so that soil conditions were easier/faster to dry and crack on the surface.

In contrast to the drip treatment, it shows that the condition of the soil on the surface remains in a moist state, presumably because the minerals in the soil remain wet and do not experience shrinking so that there are no cracks on the surface. Sunarminto and Santosa (2008) stated that the higher the COLE value in the soil, the more water application with intermittent time would cause the frequency of the shrinking process to be more significant. Cracks in the soil occur due to the high content of clay fractions and the type of clay minerals possessed by Vertisols. As a result of these cracks, soil will be exchanged between the surface and sub-surface of the soil. According to Hardjowigeno (2003), the high clay content in Vertisols can come from soil parent material (limestone, sea clay deposits) or the result of weathering of the parent material (e.g., from basalt rock). Furthermore, according to Munir (1996), cracks in Vertisols occur in the dry season due to the constriction of clay minerals 2: 1.

In the results of observations of plant height and dry weight of plants, water treatment on a surface basis is not significantly different from the treatment of water given by drops. However, when viewed from the volume of water given, the treatment by drops with a moisture content of 75% FC (M2A2) has a higher dry weight than others, while when compared to the treatment of direct water on the surface the results are not different shown in the water content of 100% FC (M1A1). In contrast, the lowest dry weight was obtained in surface water treatment with a moisture content of 50% FC (M1R3). The

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Jika dirasa juga seperti itu, maka masih perlu menambahkan penjelasan kenapa "drip treatment" tidak menyebabkan rekahan. Bisa tambahkan dari literatur ya

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provision of moisture content according to field capacity does not guarantee the production of good plant growth. From the results of Table 5 and Table 6, the treatment of drip water with a moisture content of 75% FC (M2A2) is better than the water content of 100% FC (M2A1). This fact occurs in the treatment conditions of 75% FC (A2), where 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 affects almost every metabolic process of plants. The low productivity in the treatment of surface water with a moisture content of 50% FC (M1R3) is thought to be because the condition of the Vertisols soil is dominated by micropores which are almost filled with water so that the air in the soil is reduced. According to Jasminarni (2008), the planting media becomes anaerobic when the amount of water in the planting media is excessive; conditions like this will harm growth because it interferes with plants' photosynthesis and metabolic processes. On the results of observations of the length of the roots of the plant, the difference in the average value of the treatment was seen to be very significant. The maximum root length is at the treatment of drip water (M2) with a moisture content of 25% FC (A4). This is related to the resistance of plants in times of water shortage. It is suspected that in times of lack of water, the plant extends its roots to the part of the soil with sufficient water availability so the plant can survive. Plants that experience water shortages can take water to the maximum with increased expansion and depth of the root system (Ai & Patricia, 2013). An efficient root system will increase the transport rate and the amount of water transported to the canopy, reduce water loss through the epidermis and reduce heat absorption through leaf rolling or folding (Supijatno, 2012). Inversely proportional to the length of the roots at the treatment of surface administration (M1), a moisture content of 25% FC (A4) indicates the minimum root length. The dense structure of the soil will inhibit the rate of penetration of the roots more deeply. Because the dense soil is difficult to penetrate the roots, the root lengthening area is getting shorter. In soils with a high-density level, the total length of their roots is low. Rusdiana et al. (2000) argue that if the density of the soil increases, then the macro pore space decreases, and root penetration is inhibited.

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Berdasarkan kalimat tersebut dan Jika mengacu pada data, maka seharusnya dry weight M1A2 < M1A3 karena jumlah air pada A2 lebih besar. Sehingga literatur tersebut bertentangan dengan apa yang diperoleh ya

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CONCLUSION

Gradual or continuous provision 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 manner and amount of water applied affects the level and depth of cracks, vegetative growth, and rooting of maize on Vertisols. Therefore, gradual or continuous provision of water in limited quantities (75% of field capacity) is more effective and efficient.

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SOIL MOISTURE 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 factorial 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 pots were obtained in total~~in total~~. The water is given through the surface and drops with a moisture content of 100%, 75%, 50%, and 25% of the field capacity. The results showed that the Vertisols Jeneponto had a moisture content of 24.60% (field capacity moisture 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 moisture 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: Vertisols, water content, swelling, shrinking

INTRODUCTION

Plants need soil management, including water supply, and will affect soil properties, especially those related to soil density, holding water, and groundwater resistance. One type of soil that needs improvement in its utilization is the Vertisols soil type. Vertisols is a type of soil with relatively high clay content and generally consists of a 2:1 clay mineral predominantly smectitic mineralogy with a high water holding capacity but also with a high water resistance available to plants. The low water available to plants, especially in relatively dry areas, causes water-deficient plants to be unable to grow optimally. Soil Survey Staff (2014); Prasetyo (2007); Wubetu (2017) characterizes Vertisols as a type of soil that is dark grey to blackish, has a clay texture > 30%, has slickened sides; and fracturing that can periodically open and close with a clay mineral composition dominated by clay minerals of type 2: 1. Deep and wide cracks characterize them and have gilgai microrelief with frequent micro knolls and micro-depressions (Wubetu, 2017). These soils have characteristic cyclic pedons, which make them different from other soils. Vertisols are soil whose utilization prospects are pretty good based on their chemical properties, but the obstacle is in terms of soil management which is relatively quite tricky due to the influence of the physical properties of these Vertisols. Based on the results of field surveys, in dry conditions, the soil is hard and experiences

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cracks on the soil surface 1 cm wide and at a depth of 10 to 50 cm. This condition became a severe constraint to the farmers in the cultivation of crops because it affected crop productivity. Cracks problems occur due to the lack of water availability which affects the physical properties of Vertisols. According to Mukanda and Mapiki (2001), the problem of the physical properties of this soil is in the form of heavy clay texture, swelling and shrinking properties, low infiltration speed, and slow water drainage. Other constraints on Vertisols from environmental factors, namely naturally limited water availability and heavy soil management. The type of clay mineral montmorillonite influences these constraints. The negative impact of montmorillonite shrinking on agricultural cultivation is that if the cracks are wide, they will break the root tissue for annuals (Sunarminto & Santosa, 2008). Vertisols soil management needs to keep cracks to a minimum by regulating the water supply. According to Jasminarni (2008), the need for water by plants is measured based on the percentage of field capacity. Furthermore, from the results of Suwarto's research (2003), it was reported that the highest maize growth yield was in the treatment of field capacity soil conditions. This soil requires excellent and proper water management to be suitable for plant growth.

MATERIALS AND METHODS

This research is trial research conducted at the greenhouse of the Faculty of Agriculture, Hasanuddin University, Makassar, Indonesia. Soil samples were obtained from Bangkala District, Jeneponto Regency, South Sulawesi Province, Indonesia (location shown in Figure 1) compositely from a depth of 60 cm, which was then put into a pot experiment. The study used a factorial design with two factors, namely the factor of giving water as many as 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 combination of treatments there were eight, and each combination of treatments was repeated three times so that 24 experimental pots were obtained. The soil that has been taken is compositely cleaned of rocks or the roots of the carried plants. Then mash and then put in a pot of 10 kg. A portion of the soil is taken for the analysis of physical properties. The soil that has been put in a pot and then planted with maize seeds 5 cm deep, as much as 2 seeds per pot. For the treatment of drops, previously, an infusion device has been paired with a difference in drip time adjusted to the treatment. The fertilizer is applied three days after planting with a dose of N fertilizer of 300 kg ha^{-1}. Fertilizer is immersed into the soil 5 cm deep in a circle with a distance of 5 cm from the seeds and then re-covered with soil.

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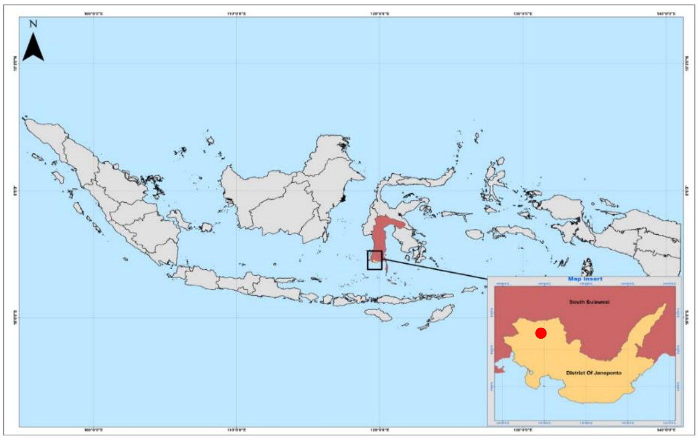

Fig 1. Vertisols soil sampling location (red dot)

Watering is carried out to regulate the moisture content of the growing medium following the treatment. The moisture content in the planting medium is sought to remain constant during observation. For the treatment of watering water on the surface, the application of water according to the treatment continues every three days after watering (according to the preliminary observations that have been made where cracks in the soil begin to occur on the third day after watering). For drip treatment, water is given daily until it reaches the moisture content according to the treatment while still adjusting the time limit from the initial observation—determination of moisture content in the treatment based on the percentage of field capacity. Gravimetric methods carry out the determination of field capacity. The separation of water by heating is commonly called the gravimetric method and is a method of measuring directly (Topp & Ferre, 2002). The gravimetric method is the simplest conceptually in determining the moisture content of the soil. Observations include measurements of plant height carried out once a week and observations of cracks on the soil surface carried out before watering. The height of maize was measured starting from the lower base stems (border with the soil surface) to the tip of the top leaf. Harvesting is carried out upon reaching the flowering phase at 64 DAP (the day after planting). After harvesting, the roots of the plant were cleaned of the soil that is still attached before measuring the length of the roots. The length of the roots was measured in a fresh and clean state of the soil. Measurements are not made on the root hairs. Measurement of root length was carried out according to the root structure in the root system according to the classification of Rao and Ito (1998), which consists of the main root (*tap root*), primary root, secondary *root*, and tertiary root. In this experiment, root length was measured by measuring the length of the primary root only using a bar meter. The observation parameters observed in this study were bulk density (ring volumetric), texture (hydrometer), structure, consistency, plasticity, coefficient of linear extensibility (COLE) value, the water content of field capacity (gravimetric), and water content of permanent wilting point (pressure plate apparatus), width and depth of soil cracks (cm), plant height (cm), dry weight of plants (g) and length of plant roots (cm).

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RESULT AND DISCUSSION

The results of the analysis of soil physical properties (see Table 1) show that the COLE value of Vertisols soil from Jeneponto is worth 0.24, which means that this soil has a high soil swelling shrinking power. The corrugation rate of COLE > 0.06 is a critical limit for unstable soils (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)	Plasticity 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 dark in color with a dominating clay fraction of 82% and a high COLE value of 0.24. As per the determination of Hardjowigeno (2003), the COLE value > 0.09 (high) indicates that the soil expands and shrivels markedly, and the content of montmorillonite is high. This is because vertisols soils are dominated by clay fractions which means that these soils have a fine fraction size. In other words, they have a large number of particles and a wider surface area per unit weight of the soil so that the particles per unit volume of the soil are increasingly denser, followed by the magnitude of the bulk density value. This is according to the statement of Hanafiah (2010) that the smaller the fraction size, the more the number and the more surface area per unit of soil weight, which means that the more micropore size is formed.

The COLE values and high clay fraction levels will encourage a more extensive swelling process of soil so that in the crushing process, it will produce finer-sized lumps. According to Fanning and Fanning (1989), the COLE value of > 0.061 soils has a severe level of shrinkage. Furthermore, according to Sunarminto and Santosa (2008), the nature of the shrinkage from montmorillonite clay is the cause of the formation of slickened sides and gilgai microrelief (cauliflower structure), as well as the process of pedoturbation on Vertisols. The influence of technical treatment of water giving on the soil of Vertisols can be observed from the depth and width of these soil cracks. Figures 2 and 3 show a significant difference between the soil water on the surface and that given water in drops. Observations are carried out simultaneously after three days of water-giving treatments.

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M1A1 M1A2 M1A3 M1A4

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

M1A1 M1A2 M1A3 M1A4

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

Based on Figures 2 and 3, the soil cracks only occur on the surface water watering treatment (M1); the treatment of 100% FC cracks occur somewhat enormously and decreases the amount of water given (75%, 50%, and 25% of FC) as small as the width of the cracks that occur on the surface. Meanwhile, in the drip treatment (M2), the soil condition at the treatment of 100%, 75%, 50%, and 25% of FC has the same soil conditions. Namely, it remains in a moist and loose state so that there are no cracks/fracturing on the soil surface. In Table 2, the treatment of direct water application on the surface with a moisture content of 50% FC (M1A3) and a moisture content of 25% FC (M1A4) experienced cracks on the second day after watering. The treatment of moisture content of 100% FC (M1A1) and moisture content of 75% FC (M1A2) experienced cracks on the third day after watering. While in the drip treatment, the surface on the ground does not experience cracks. The soil Vertisols' average cracking can be seen in the treatment of watering water on the surface with a moisture content of 100% FC (M1A1), shows the highest value of soil cracks with a crack width_of > 0.18 cm and a depth of > 1.30 cm. Meanwhile, the treatment with a moisture 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. The analysis of treatment interactions with plants showed that the interaction between water feeding and different moisture content had a noticeable effect in increasing plant height. Observation of maize crop height was carried out for nine weeks. The results of the minor real difference test can be seen in Table 4.

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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)

Water giving	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^{from}
BNT 0,0518,39				

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

Table 5 shows data that there was a significant difference between the treatment of water watering on the surface (M1). The water content of 100% FC (A1) showed a markedly different plant height with the treatment of water content of 50% FC (A3) and 25% FC (A4) and did not differ markedly from the treatment of 75% FC(A2)); water content of 75% FC indicates that the plant height is less than optimum, the water content of 50% FC and the water content of 25% FC indicate that the plant height has begun to be disturbed. In the drip water treatment (M2), the maximum plant height was obtained at a moisture content of 75% FC (A2) and differed markedly from the treatment of water content of 100% FC (A1) and 25% FC (A4) and did not differ markedly from the water

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content of 50% FC (A3). At a moisture content of 50% FC and a moisture content of 25% FC, the plant height is in a less-than-optimum state. The treatment of water in drops with a moisture content of 75% FC (M2A2) showed the highest plant height value, 125.2 cm. Meanwhile, the treatment of water on a surface basis with a volume of 100% FC (M1A1) showed a maximum plant height value of 122.70 cm, but it did not differ markedly from the moisture content of 75% FC in the drip treatment. The distinction between the giving of water and different moisture content has a noticeable effect in increasing the dry weight of the plant. Observation of the dry weight of the plant is carried out after harvest. The results of the minor real difference test can be seen in Table 5.

Table 5. A dry weight of maize (g)

Water giving	Water content			
	A1	A2	A3	A4
		g		
M1	63,07[c]	43.67[from]	29,67[a]	33,33[a]
M2	31,93[a]	54,80[bc]	39,67[a]	38,47[a]
BNT 0,0514,11				

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 fundamental difference between the treatment given. In the surface water treatment (M1), the moisture content of 100% FC (A1) indicates the maximum dry weight and differs markedly from other water content treatments (A2, A3, and A4), which show a less than optimum dry weight. Nevertheless, the maximum dry weight on surface treatment with 100% FC (M1A1) does not differ markedly from the treatment in drops with 75% FC (M2A2). The treatment of surface water with a moisture content of 100% FC (M1A1) and drip treatment with a water content of 75% FC (M2A2) showed the results of the BNT test with a level of 0.05, which did not differ markedly. The optimum dry weight value with the provision of a minimum volume of water, indicated by the treatment in drops with a moisture content of 75% FC (M2A2), which is 54.8 g. Meanwhile, the surface watering treatment with a moisture content of 50% FC (M1A3) showed the lowest dry weight value of 29.7 g. The amount of water given by drops is less than on a surface basis. The results of the fingerprint analysis showed that the interaction between water giving and different moisture content significantly affected the length of plant roots. Data on the length of plant roots are shown in Table 6.

Table 6. Plant root length

Water feeding	Water content			
	A1	A2	A3	A4
		cm		
M1	107,10[abc]	95.30[from]	93.53[from]	91.20[from]
M2	87,27[a]	80,10[a]	116,27[bc]	124,20[c]
BNT 0,0527,54				

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

Commented [r41]: Watering method

Commented [r42]: Why it is feeding while others giving?

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Based on the data in Table 6, there is a noticeable difference between the treatments given. In the surface water watering treatment (M1), the moisture content of 100% FC (A1) indicates the optimum root length, the moisture content of 75% FC (A2), the moisture content of 50% FC (A3), and the water content of 25% FC (A4) indicates the root length is less than optimal. At the drip water treatment (M2), the moisture content of 100% FC (A1) and the moisture content of 75% FC (A2) indicate that the root length is disturbed, but the moisture content of 50% FC (A3) and the moisture content of 75% FC (A4) indicate the optimum root length. The treatment of drip water with a volume of 25% FC (M2A4) showed the highest root length value with the provision of a minimum volume of water, which is 124.2 cm. While the treatment of water in drops with a volume of 75% FC (M2A2) showed the lowest root length value of 80.1 cm. For the maximum ratio of roots obtained at administration in drops with a moisture content of 25% of the roomy capacity.

Vertisols soil use will be optimal if followed by water feeding. In the results 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 state. The average crack in the administration of water content of 100% FC (A1) and water content of 75% FC (A2) occurs every three days after watering, while in the administration, the moisture content of 50% FC (A3) and the moisture content of 25% FC (A4) occurs every two days after watering. Vertisols having high montmorillonite clay will make the soil effortlessly float during watering. However, a different way of giving water will affect the shrinking of these 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, there was a drastic dehumidifier, allegedly due to the shrinkage of type 2: 1 clay minerals by Vertisols, so that soil conditions were easier/faster to dry and crack on the surface.

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In contrast to the drip treatment, it shows that the condition of the soil on the surface remains in a moist state, presumably because the minerals in the soil remain wet and do not experience shrinking so that there are no cracks on the surface. Sunarminto and Santosa (2008) stated that the higher the COLE value in the soil, the more water application with intermittent time would cause the frequency of the shrinking process to be more significant. Cracks in the soil occur due to the high content of clay fractions and the type of clay minerals possessed by Vertisols. As a result of these cracks, soil will be exchanged between the surface and sub-surface of the soil. According to Hardjowigeno (2003), the high clay content in Vertisols can come from soil parent material (limestone, sea clay deposits) or the result of weathering of the parent material (e.g., from basalt rock). Furthermore, according to Munir (1996), cracks in Vertisols occur in the dry season due to the constriction of clay minerals 2: 1.

In the results of observations of plant height and dry weight of plants, water treatment on a surface basis is not significantly different from the treatment of water given by drops. However, when viewed from the volume of water given, the treatment by drops with a moisture content of 75% FC (M2A2) has a higher dry weight than others, while when compared to the treatment of direct water on the surface the results are not different shown in the water content of 100% FC (M1A1). In contrast, the lowest dry weight was obtained in surface water treatment with a moisture content of 50% FC (M1R3). The

provision of moisture content according to field capacity does not guarantee the production of good plant growth. From the results of Table 5 and Table 6, the treatment of drip water with a moisture content of 75% FC (M2A2) is better than the water content of 100% FC (M2A1). This fact occurs in the treatment conditions of 75% FC (A2), where 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 affects almost every metabolic process of plants. The low productivity in the treatment of surface water with a moisture content of 50% FC (M1R3) is thought to be because the condition of the Vertisols soil is dominated by micropores which are almost filled with water so that the air in the soil is reduced. According to Jasminarni (2008), the planting media becomes anaerobic when the amount of water in the planting media is excessive; conditions like this will harm growth because it interferes with plants' photosynthesis and metabolic processes. On the results of observations of the length of the roots of the plant, the difference in the average value of the treatment was seen to be very significant. The maximum root length is at the treatment of drip water (M2) with a moisture content of 25% FC (A4). This is related to the resistance of plants in times of water shortage. It is suspected that in times of lack of water, the plant extends its roots to the part of the soil with sufficient water availability so the plant can survive. Plants that experience water shortages can take water to the maximum with increased expansion and depth of the root system (Ai & Patricia, 2013). An efficient root system will increase the transport rate and the amount of water transported to the canopy, reduce water loss through the epidermis and reduce heat absorption through leaf rolling or folding (Supijatno, 2012). Inversely proportional to the length of the roots at the treatment of surface administration (M1), a moisture content of 25% FC (A4) indicates the minimum root length. The dense structure of the soil will inhibit the rate of penetration of the roots more deeply. Because the dense soil is difficult to penetrate the roots, the root lengthening area is getting shorter. In soils with a high-density level, the total length of their roots is low. Rusdiana et al. (2000) argue that if the density of the soil increases, then the macro pore space decreases, and root penetration is inhibited.

CONCLUSION

Gradual or continuous provision 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 manner and amount of water applied affects the level and depth of cracks, vegetative growth, and rooting of maize on Vertisols. Therefore, gradual or continuous provision of water in limited quantities (75% of field capacity) is more effective and efficient.

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SOIL ~~MOISTURE~~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 ~~factorial~~ 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 ~~moisture~~water content of 100%, 75%, 50%, and 25% of the field capacity. The results showed that the Vertisols Jeneponto had an available ~~moisture~~water water content of 24.60% (field capacity ~~moisture~~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 ~~moisture~~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, ~~swelling, shrinking~~

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

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Commented [M6]: Kalimat ini sedikit membingungkan karena terlalu panjang. Terutama setelah "as well as…..", nah ini ada apa dengan penggunaan air dalam jumlah yang sedikit….jadi sebaiknya ini dipecah menjadi 2 kallimat sehingga penyusunannya dalam Bahasa inggris juga menjadi lebih sistematis.

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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).Plants need soil management, including water supply, and will affect soil properties, especially those related to soil density, holding water, and groundwater resistance. One type of soil that needs improvement in its utilization is the Vertisols soil type. Vertisols is a type of soil with relatively high clay content and generally consists of a 2:1 clay mineral predominantly smectitic mineralogy with a high water holding capacity but also with a high water resistance available to plants. The low water available to plants, especially in relatively dry areas, causes water-deficient plants to be unable to grow optimally. Soil Survey Staff (2014); Prasetyo (2007); Wubetu (2017) characterizes Vertisols as a type of soil that is dark gray to blackish, has a clay texture > 30%, has slickened sides; and fracturing that can periodically open and close with a clay mineral composition dominated by clay minerals of type 2: 1. Deep and wide cracks characterize them and have gilgai microrelief with frequent micro knolls and micro depressions (Wubetu, 2017). These soils have characteristic cyclic pedons, which make them different from other soils. Vertisols are soil whose utilization prospects are pretty good based on their chemical properties, but the obstacle is in terms of soil management which is relatively quite tricky due to the influence of the physical properties of these Vertisols. Based on the results of field surveys, in dry conditions, the soil is hard, and experiences cracks on the soil surface with 1 cm wide and at a depth of 10 to 50 cm. This condition became a severe constraint to the farmers in the cultivation of crops because it affected crop productivity. Cracks problems occur due to the lack of water availability which affects the physical properties of Vertisols. According to Mukanda and Mapiki (2001), the problem of the physical properties of this soil is in the form of heavy clay texture, swelling and shrinking properties, low infiltration speed, and slow water drainage. Other constraints on Vertisols from environmental factors, namely naturally limited water availability and heavy soil management. The type of clay mineral montmorillonite influences these constraints. The negative impact of montmorillonite shrinking on agricultural cultivation is that if the cracks are wide, they will break the root tissue for annuals (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.Vertisols soil management needs to keep cracks to a minimum by regulating the water supply. According to Jasminarni (2008), the need for water by plants is measured based on the percentage of 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. Furthermore, from the results of Suwarto's research (2003), it was reported that the highest maize growth yield was in the treatment of field capacity soil conditions. This soil requires excellent and proper water management to be suitable for plant growth.

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Commented [M15]: Mungkin bisa pakai istilah lain yang lebih tepat, bukan pretty….

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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. This research is trial research conducted at the greenhouse of the Faculty of Agriculture, Hasanuddin University, Makassar, Indonesia. Soil samples were obtained from Bangkala District, Jeneponto Regency, South Sulawesi Province, Indonesia (location shown in Figure 1) compositely from a depth of 60 cm, which was then put into a pot experiment. The study used a factorial design with two factors, namely the factor of giving water as many as 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 combination of treatments there were eight, and each combination of treatments was repeated three times so that 24 experimental pots were obtained. The soil that has been taken is compositely cleaned of rocks or the roots of the carried plants. Then mash and then put in a pot of 10 kg. A portion of the soil is taken for the analysis of physical properties. The soil that has been put in a pot and then planted with maize seeds 5 cm deep, as much as 2 seeds per pot. For the treatment of drops, previously, an infusion device has been paired with a difference in drip time adjusted to the treatment. The fertilizer is applied three days after planting with a dose of N fertilizer of 300 kg ha^{-1}. Fertilizer is immersed into the soil 5 cm deep in a circle with a distance of 5 cm from the seeds and then re-covered with soil.

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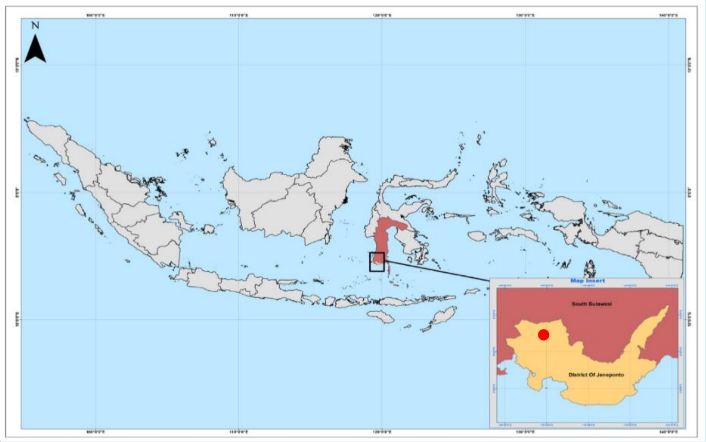

Fig 1. Vertisols soil sampling location (red dot)

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). ~~Watering is carried out to regulate the moisture content of the growing medium following the treatment. The moisture content in the planting medium is sought to remain constant during observation. For the treatment of watering water on the surface, the application of water according to~~

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Legenda peta juga perlu dilengkapi, karena jika seperti ini seperti peta buta, salah satunya karena pembaca diminta menebak sendiri di mana lokasi sample....

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Commented [M24]: Following di sini sepertinya kurang tepat ya..silahkan cari istilah yang lebih tepat ya the treatment continues every three days after watering (according to the preliminary observations that have been made where cracks in the soil begin to occur on the third day after watering). For drip treatment, water is given daily until it reaches the moisture content according to the treatment while still adjusting the time limit from the initial observation – determination of moisture content in the treatment based on the percentage of field capacity. Gravimetric methods carry out the determination of field capacity. The separation of water by heating is commonly called the gravimetric method and is a method of measuring directly (Topp & Ferre, 2002). The gravimetric method is the simplest conceptually in determining the moisture content of the soil. Observations include measurements of plant height carried out once a week and observations of cracks on the soil surface carried out before watering. The height of maize was measured starting from the lower base stems (border with the soil surface) to the tip of the top leaf. Harvesting is carried out upon reaching the flowering phase at 64 DAP (the day after planting). After harvesting, the roots of the plant were cleaned of the soil that is still attached before measuring the length of the roots. The length of the roots was measured in a fresh and clean state of the soil. Measurements are not made on the root hairs. Measurement of root length was carried out according to the root structure in the root system according to the classification of Rao and Ito (1998), which consists of the main root (*tap root*), primary root, secondary *root*, and tertiary root. In this experiment, root length was measured by measuring the length of the primary root only using a bar meter. The observation parameters observed in this study were bulk density (ring volumetric), texture (hydrometer), structure, consistency, plasticity, coefficient of linear extensibility (COLE) value, the water content of field capacity (gravimetric), and water content of permanent wilting point (pressure plate apparatus), width and depth of soil cracks (cm), plant height (cm), dry weight of plants (g) and length of plant roots (cm).

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

Commented [M25]: Cek grammer ya

Nama analisis sebenarnya untuk bisa mengukur KA kapasitas lapang?

Commented [M26]: Parameter observasi umumnya mengacu pada observasi lapangan. Dengan demikian akan lebih baik dibedakan mana parameter observasi lapang, dan mana parameter yang dianalisis di laboratorium

Commented [M27]: Ini apakah maksudnya KA biasa yang menunjukkan bagaimana kondisi di lapang sesungguhya? Bukan KA KL yang ditentukan dengan pressure plate apparatus? Jika memang bukan, lalu mneghitung kadar air tersedia (available water) yang di tabel 1, bagaimana?

Commented [RN28R27]: Kadar air kapasitas lapang ditetapkan dengan metode gravimetric sedangkan penentuan titik layu permanen ditetapkan dengan menggunakan pressure chamber.

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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)	Plasticity cConsistency (wet)	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 swelling 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. Table 1 shows that the Vertisols soil sample in this study is dark in color with a dominating clay fraction of 82% and a high COLE value of 0.24. As per the determination of Hardjowigeno (2003), the COLE value > 0.09 (high) indicates that the soil expands and shrivels markedly, and the content of montmorillonite is high. This is because vertisols soils are dominated by clay fractions which means that these soils have a fine fraction size. In other words, they have a large number of particles and a wider surface area per unit weight of the soil so that the particles per unit volume of the soil are increasingly denser, followed by the magnitude of the bulk density value. This is according to the statement of Hanafiah (2010) that the smaller the fraction size, the more the number and the more surface area per unit of soil weight, which means that the more micropore size is 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

Commented [M29]: Ini angkanya persis seperti ini? Tidak ada desimalnya?

Commented [M30]: Apakah yakin sturktur tanahnya berbentuk prismatik?

Commented [RN31R30]: Bentuk struktur tanah yang ditemukan di lapangan prismatik

Commented [M32]: Tidak ada istilah ini di dalam penetapan plastisitas. Perlu dipastikan dulu kembali, konsistensi basah yang telah ditentukan, apakah menetapkan sifat plastic atau melekat? Jika plastisitas, maka istilah wet sticky itu tidak ada dalam penetapan plastisitas, mohon dicek kembali dan tentukan istilah Bahasa inggrisnya dengan tepat, karena dalam penetapan sifat melekat, juga tidak ada istilah "wet sticky"

Commented [M33]: Belum disebutkan metodenya di bagian metode

Commented [RN34R33]: Metode pengukuran pengembangan dan pengerutn tanah adalah metode pengukuran nilai COLE

Commented [M35]: Belum disebutkan metodenya di bagian metode

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Commented [M36]: Di dalam tabel tersebut tidak menunjukkan warna tanah

Commented [M37]: Perlu dilengkapi, "small size particle" or what?

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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. The COLE values and high clay fraction levels will encourage a more extensive swelling process of soil so that in the crushing process, it will produce finer-sized lumps. According to Fanning and Fanning (1989), the COLE value of > 0.061 soils has a severe level of shrinkage. Furthermore, according to Sunarminto and Santosa (2008), the nature of the shrinkage from montmorillonite clay is the cause of the formation of slickened sides and gilgai microrelief (cauliflower structure), as well as the process of pedoturbation on Vertisols. The influence of technical treatment of water giving on the soil of Vertisols can be observed from the depth and width of these soil cracks. Figures 2 and 3 show a significant difference between the soil water on the surface and that given water in drops. Observations are carried out simultaneously after three days of water-giving treatments.

M1A1 M1A2 M1A3 M1A4

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

M21A1 M21A2 M21A3 M21A4

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

Commented [M38]: Level? Or content? Mana yang lebih tepat?

Commented [M39]: Apa bener perbedaan ini yang terlihat dari gambar? BUkannya perbedaan permukaan tanah karena kedua perlakuan tersebut?

Commented [M40]: M1 apa M2?

Commented [RN41R40]: M2

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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. Based on Figures 2 and 3, the soil cracks only occur on the surface water watering treatment (M1); the treatment of 100% FC show that cracks occur somewhat enormously and decreases the amount of water given (75%, 50%, and 25% of FC) as small as the width of the cracks that occur on the surface. Meanwhile, in the drip treatment (M2), the soil condition at the treatment of 100%, 75%, 50%, and 25% of FC has the same soil conditions. Namely, it remains in a moist and loose state so that there are no cracks/fracturing on the soil surface. In Table 2, the treatment of direct water application on the surface with a moisture content of 50% FC (M1A3) and a moisture content of 25% FC (M1A4) experienced cracks on the second day after watering. The treatment of moisture content of 100% FC (M1A1) and moisture content of 75% FC (M1A2) experienced cracks on the third day after watering. While in the drip treatment, the surface on the ground does not experience cracks. The soil Vertisols' average cracking can be seen in the treatment of watering water on the surface with a moisture content of 100% FC (M1A1), shows the highest value of soil cracks with a crack width of > 0.18 cm and a depth of > 1.30 cm. Meanwhile, the treatment with a moisture 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. The analysis of treatment interactions with plants showed that the interaction between water feeding and different moisture content had a noticeable effect in increasing plant height. Observation of maize crop height was carried out for nine weeks. The results of the minor real difference test can be seen 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

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Commented [M42]: Susun ulang ya kalimatnya, ini agak susah dipamahi, terutama penggunaan istilah " as small as" di sini

Commented [M43]: Setelah dua kalimat ini, perlu diberi tambahan penjelasan, misalnya, kenapa KA 100 FC menghasilkan rekahan yang lebih besar dibandingkan saat diberikan KA yang lebih rendah.

Commented [M44]: Ini sebaiknya jadi paragraph terpisah.? Bisa disatukan dengan paragraph di bawah tabel 4,

Dan pada paragraph ini perlu ditambahkan pembahasannya, missal mengapa perbedaan cara pemberian air dan jumlah air yang ditambahkan berpengaruh terhadap peningkatan tinggi tanaman? Perlu juga dibahas terkait cara M2, kenapa tinggi tanaman yang A2 lebih tinggi dibandingkan A1? Karena apa yang disampaikan pada pargraf ini baru sebatas menerangkan isi tabel saja, belum ada pembahasannya

Commented [M45]: Judul tabel perlu dilengkapi dengan perlakuan mana

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)

Water givingIrrigation 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]from
BNT 0,0518,39				

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 shows data that there was a significant difference between the treatment of water watering on the surface (M1). The water content of 100% FC (A1) showed a markedly different plant height with the treatment of water content of 50% FC (A3) and 25% FC (A4) and did not differ markedly from the treatment of 75% FC(A2)); water content of 75% FC indicates that the plant height is less than optimum, the water content of 50% FC and the water content of 25% FC indicate that the plant height has

Commented [M46]: Sama seperti komentar di atas

Table 3 belum diacu di dalam text

Commented [M47]: Titik2 di sini seharusnya tidak sampai pada kolom "water giving"

Commented [M48]: Belum ada keterangan ini di bawah tabel? Apa mungkin ini salah ketik? Cek kesesuaiannya dengan penjelasan pada paragraph di bawahnya

Commented [M49]: Keternagan ini masih kurang,…angka diikuti hurus sama, angka yang mana? Pada kolom atau baris?

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Commented [M50]: Tabel 4 apa 5?

Commented [M51]: Antara M1 dengan apa? Kalimat ini sepertinya belum selesai

Commented [M52]: Mungkin akan lebih baik jika dilengkapi seperti ini: pemberian kadar air 75% mengindikasikan…..

Karena akan kurang tepat jika hanya: KA 75% mengindikasikan tinggi tanaman….seperti ada yang kurang…cek kalimat yang lain ya

Commented [M53]: Dari mana menyimpulkan bahwa pada KA ini pertumbuhan tinggi tanaman paling optmum? Apa ada literatur pendukung? Perlu ditambahkan ya begun to be disturbed. In the drip water treatment (M2), the maximum plant height was obtained at a moisture content of 75% FC (A2) and differed markedly from the treatment of water content of 100% FC (A1) and 25% FC (A4) and did not differ markedly from the water content of 50% FC (A3). At a moisture content of 50% FC and a moisture content of 25% FC, the plant height is in a less-than-optimum state. The treatment of water in drops with a moisture content of 75% FC (M2A2) showed the highest plant height value, 125.2 cm. Meanwhile, the treatment of water on a surface basis with a volume of 100% FC (M1A1) showed a maximum plant height value of 122.70 cm, but it did not differ markedly from the moisture content of 75% FC in the drip treatment. The distinction between the giving of water and different moisture content has a noticeable effect in increasing the dry weight of the plant. Observation of the dry weight of the plant is carried out after harvest. The results of the minor real difference test can be seen in Table 5.

Table 5. A dry weight of maize (g)

Water givingIrrigation way	Water content A1	A2	A3	A4
	.... g			
M1	63,07^{c}	43.67^{fromab}	29,67^{a}	33,33^{a}
M2	31,93^{a}	54,80^{bc}	39,67^{a}	38,47^{a}
BNT 0,0514,11				

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. In Table 5, it can be seen that there is a fundamental difference between the treatment given. In the surface water treatment (M1), the moisture content of 100% FC (A1) indicates the maximum dry weight and differs markedly from other water content treatments (A2, A3, and A4), which show a less than optimum dry weight. Nevertheless, the maximum dry weight on surface treatment with 100% FC (M1A1) does not differ markedly from the treatment in drops with 75% FC (M2A2). The treatment of surface water with a moisture content of 100% FC (M1A1) and drip treatment with a water content of 75% FC (M2A2) showed the

Commented [M54]: Kalimat ini terlalu panjang, pecah menjadi dua kalimat

Commented [M55]: Darimana menyatakan ini kurang dari optimum? Perlu acuan literatur lain untuk menguatkan pernyataan yang ditulis.

Commented [M56]: Perlu ditambah penjelasan, kenapa hal ini terjadi

Commented [M57]: Ini sebaiknya paragraph terpisah karena sudah membahas parameter yang berbeda, bisa disatukan dengan paragraph di bawah tabel 5.

Commented [M58]: Paragraph di bawah tabel 5 baru sebatas menerangkan isi tabel, belum ada penjelasan missal kenapa perlakuan M1A1 menyebabkan bobot kering paling tinggi?

Commented [M59]: Ini from?

Sedangkan di bawah tabel tidak ada keterangan terkait ini. Apa mungkin ada kesalahan ketik?

Karena dari penjelasan pada paragraph di atasnya dikatakan A1 tidak berbeda nyata dengan A2.

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Commented [M60]: Nilai optimumnya yang mana?

results of the BNT test with a level of 0.05, which did not differ markedly. The optimum dry weight value with the provision of a minimum volume of water, indicated by the treatment in drops with a moisture content of 75% FC (M2A2), which is 54.8 g. Meanwhile, the surface watering treatment with a moisture content of 50% FC (M1A3) showed the lowest dry weight value of 29.7 g. The amount of water given by drops is less than on a surface basis. The results of the fingerprint analysis showed that the interaction between water giving and different moisture content significantly affected the length of plant roots. Data on the length of plant roots are shown in Table 6.

Table 6. Plant root length

Water feedingIrrigation	Water content			
	A1	A2	A3	A4
	cm			
M1	107,10[abc]	95.30[abfrom]	93.53[abfrom]	91.20[abfrom]
M2	87,27[a]	80,10[a]	116,27[bc]	124,20[c]
BNT 0,0527,54				

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.Based on the data in Table 6, there is a noticeable difference between the treatments given. In the surface water watering treatment (M1), the moisture content of 100% FC (A1) indicates the optimum root length, the moisture content of 75% FC (A2), the moisture content of 50% FC (A3), and the water content of 25% FC (A4) indicates the root length is less than optimal. At the drip water treatment (M2), the moisture content of 100% FC (A1) and the moisture content of 75% FC (A2) indicate that the root length is disturbed, but the moisture content of 50% FC (A3) and the moisture content of 75% FC (A4) indicate the optimum root length. The treatment of drip water with a volume of 25% FC (M2A4) showed the highest root length value with the provision of a minimum volume of water, which is 124.2 cm. While the treatment of water in drops with a volume of 75% FC (M2A2) showed the lowest root length value of 80.1 cm. For the maximum ratio of roots obtained at administration in drops with a moisture content of 25% of the roomy 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

Commented [M61]: Sepertinya kedua kalimat ini memiliki makna yang sama ya? Jika memang ya, bisa pilih salah satu saja ya, biar ga double

Commented [M62]: Bagaimana menentukan bahwa nilai ini yang optimum? Karena biasanya jika dikatakan optimum, itu perlu dibandingkan dengan suatu literatur tertentu yang memang penelitian terkait pertumbuhan optimum dari Jagung.

Jika nilai hanya dibandingkan antara 1 perlakuan dengan lainnya, mungkin lebih tepat dikatakan paling maksimum ya dari penelitian ini?

Commented [M63]: Kenapa jumlah air metode tetes < metode permukaan? Bukannya di metode disebutkan jumlah airnya sama?

Commented [RN64R63]: Perbedaan ini terjadi karena adanya perbedaan volume saat pemberian yang sekaligus dan yang ditetes, meskipun jumlah total air sama.

Commented [M65]: Ini jadikan paragraph baru ya

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Commented [M66]: Paragraph ini baru menerangkan isi tabel, belum ada penjelasannya. Mohon dibahas ya hasilnya. Misal dikatakan bahwa " At the drip water treatment (M2), the water content of 100% FC (A1) and the water content of 75% FC (A2) indicate that the root length is disturbed, but the water content of 50% FC (A3) and the water content of 75% FC (A4) indicate the optimum root length. Nah ini perlu dibahas kenapa dengan pemberian A1 dan A2 pada perlakuan M2 menyebabkan panjang akar terganggu.

Commented [M67]: Istilah ini kurang tepat ya

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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. Vertisols soil use will be optimal if followed by water feeding. In the results 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 state. The average crack in the administration of water content of 100% FC (A1) and water content of 75% FC (A2) occurs every three days after watering, while in the administration, the moisture content of 50% FC (A3) and the moisture content of 25% FC (A4) occurs every two days after watering. Vertisols having high montmorillonite clay will make the soil effortlessly float during watering. However, a different way of giving water will affect the shrinking of these 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, there was a drastic dehumidifier, allegedly due to the shrinkage of type 2: 1 clay minerals by Vertisols, so 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 contrast to the drip treatment, it shows that the condition of the soil on the surface remains in a moist state, presumably because the minerals in the soil remain wet and do not experience shrinking so that there are no cracks on the surface. Sunarminto and Santosa (2008) stated that the higher the COLE value in the soil, the more water application with intermittent time would cause the frequency of the shrinking process to be more significant. Cracks in the soil occur due to the high content of clay fractions and the type of clay minerals possessed by Vertisols. As a result of these cracks, soil will be exchanged between the surface and sub-surface of the soil. According to Hardjowigeno (2003), the high clay content in Vertisols can come from soil parent material (limestone, sea clay deposits) or the result of weathering of the parent material (e.g., from basalt rock). Furthermore, according to Munir (1996), cracks in Vertisols occur in 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

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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. ~~In the results of observations of plant height and dry weight of plants, water treatment on a surface basis is not significantly different from the treatment of water given by drops. However, when viewed from the volume of water given, the treatment by drops with a moisture content of 75% FC (M2A2) has a higher dry weight than others, while when compared to the treatment of direct water on the surface the results are not different shown in the water content of 100% FC (M1A1). In contrast, the lowest dry weight was obtained in surface water treatment with a moisture content of 50% FC (M1R3). The provision of moisture content according to field capacity does not guarantee the production of good plant growth. From the results of Table 5 and Table 6, the treatment of drip water with a moisture content of 75% FC (M2A2) is better than the water content of 100% FC (M2A1). This fact occurs in the treatment conditions of 75% FC (A2), where 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 affects almost every metabolic process of plants. The low productivity in the treatment of surface water with a moisture content of 50% FC (M1R3) is thought to be because the condition of the Vertisols soil is dominated by micropores which are almost filled with water so that the air in the soil is reduced. According to Jasminarni (2008), the planting media becomes anaerobic when the amount of water in the planting media is excessive; conditions like this will harm growth because it interferes with plants' photosynthesis and metabolic~~

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Commented [M75]: Apakah yakin untuk tabel 6 juga seperti ini? Cek kembali data pada Tabel 6 processes. On the results of observations of the length of the roots of the plant, the difference in the average value of the treatment was seen to be very significant. The maximum root length is at the treatment of drip water (M2) with a moisture content of 25% FC (A4). This is related to the resistance of plants in times of water shortage. It is suspected that in times of lack of water, the plant extends its roots to the part of the soil with sufficient water availability so the plant can survive. Plants that experience water shortages can take water to the maximum with increased expansion and depth of the root system (Ai & Patricia, 2013). An efficient root system will increase the transport rate and the amount of water transported to the canopy, reduce water loss through the epidermis and reduce heat absorption through leaf rolling or folding (Supijatno, 2012). Inversely proportional to the length of the roots at the treatment of surface administration (M1), a moisture content of 25% FC (A4) indicates the minimum root length. The dense structure of the soil will inhibit the rate of penetration of the roots more deeply. Because the dense soil is difficult to penetrate the roots, the root lengthening area is getting shorter. In soils with a high-density level, the total length of their roots is low. Rusdiana et al. (2000) argue that if the density of the soil increases, then the macro pore space decreases, and root penetration is inhibited.

Commented [M76]: pernyataan "the planting media becomes anaerobic when the amount of water in the planting media is excessive; conditions like this will harm growth because it interferes with plants' photosynthesis and metabolic processes" sepertinya tidak tepat dijadikan sebagai penguat dari fenomena yang terjadi.

Berdasarkan kalimat tersebut dan Jika mengacu pada data, maka seharusnya dry weight M1A2 < M1A3 karena jumlah air pada A2 lebih besar. Sehingga literatur tersebut bertentangan dengan apa yang diperoleh ya

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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.Gradual or continuous provision 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 manner and amount of water applied affects the level and depth of cracks, vegetative growth, and rooting of maize on Vertisols. Therefore, gradual or continuous provision of water in limited quantities (75% of field capacity) is more effective and efficient.

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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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Soil Water Management to Minimize Shrinkage of Vertisols

PDF

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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

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