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Improvement of Soil Physical Properties of Cambisol Using Soil Amendment

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Abstract-Managing dryland requires intergrated knowledges on soil, water and plants relationship in order to achieve maximum yield. Using local and unused resource are important not only in aspect of reducing pollution but low price and also affordable for farmers. Thus, using amendment from in situ resources is suggested by many experts. This amendmentused is assumed it could contribute improvement physical properties of soil and result better yields. This study aimed to studi more deeply on how much of soil amendmentmight improve physical properties of Cambisol under dryland environment and furthermore find out the crop responseto soilamendments. The research was conducted during July to Oct. 2016 at Gampong Paud, Muara Tiga District, Pidie District, Aceh Province with the altitude ± 30 m above sea level and slope 0-3 %. A Randomized Completely Block Design (RCBD) with two factors replicated three times was used. First factor was soil amendment consisting of 4 levels ; no amendment (control), cow manure amount 10 tons ha $^{-1}$, straw compost 10 tons ha^{-1}, and cow manure 10 tons ha $^{-1}$ + compost 10 tons ha^{-1}. The second factor was 5 varieties of peanut: *Tuban*, *Hypoma* 2, *Bima*, Kelinci and *Gajah*. The parameters observed were soil bulk density, permeability, total soil porosity, aggregate stability index, soil water holding capacity at water potential -3 and -15 bar. Results of our studies showed soil amandement improves some soil physical properties, combination amendment with variety of peanuts resulted significant effects to soil physical properties, and combination treatments mostly influenced soil physical properties at soil depth of 0 -20 cm.Addition of 10 tons ha $^{-1}$ cow manure or10 tons ha $^{-1}$ strawcompost isenough to improve soil physical properties.

Keywords: soil amendment, soil physical properties, dryland

Introduction

The current agricultural development effortsare generally carried out on marginal lands that are mostly dryland areas. Indonesia has dryland reached 144,47million ha or 76,20% of land area, spreading in Sumatra ± 33,25 million ha, Java ± 10,27 million ha, Kalimantan ± 41,61 million ha, Sulawesi ± 16,57 million ha, Maluku ± 7,45 million ha, Bali and Nusa Tenggara ± 6,70 million ha, and Papua ± 28,60 million ha (BBSDLP, 2014). Cambisol or Inceptisol is the dominant dry land soil found in Aceh Province with the unique characteristics are rather difficult to cultivate, susceptible to run-off and erosion. Soil amendment is assumed that it can rehabilitate soil degradation by increasing soil carbon content (Sohi *et al.*, 2010), surface area and cation exchange capacity (Barrow, 2012; Lee *et al.*, 2010). Changes in soil physical properties will influence the human adaptation to environment because soil physical properties can directly affect crop establishment and crop yield. Then soil physical properties also influence rate water infiltration, soil erosion and soil degradation(Blanco-Conqui and Ruis, 2018)

Soil degradation can be indicated by looking at the aggregate stability of its soil. Aggregate stability is defined as the resistance of the soil against the external destructive effects of rainfall, runoff and wind. It is also an indicator of soil structure (Six *et al.*, 2000) which is a crucial physical property to estimate the ability of a soil to resist disintegration when disruptive forces associated with tillage, rainfall, or wind erosion are applied (Deviren e*t al.*, 2012).A large number of factors that influence soil aggregation such as plant diversity and biological activity (Pohl *et al.*, 2012), grass roots (Tisdall and Oades, 1982), organic matter and tillage implement (Abdollahi e*t al*., 2014).Furthermore human activities (e.g. tillage) have also a direct effect on aggregate stability through the mechanical breakage of large clods and macroaggregates (Álvaro-Fuentes *et al*., 2008). Thus, management of soil water and manipulation of soil physical condition are important in dry land area. Practices such as tillage practices (Kuzucu and Dokmen, 2015), biochar application (Oliveira *et al*., 2017), and amendments from variety of sources have been continously conducted to find the best management practices in dry land area.

Soil amendments is defined as any materials we add into the soil in order to improve the quality of the soils. Many materials are used to act as soil amendments, the two of them were used in this study that is cow manure and straw compost. Those materials were selected because they are easy to obtain, not yet used by many farmers and could reduce water contamination/ pollutants. Furthermore, soil amendment mostly has low soil bulk density, high porosity, and ease the roots to penetrate into the soil. Hickman and Whitney (1990) stated that soil amendments will prevent evaporation on the soil, and increase soil water holding capacity. However, addition of uncontrolled and unmeasurable soil amendment might create groundwater pollution. Therefore, the use of soil amendment should follow the criteria of being safe, using lower price, locally available, and renewable.

Cow manure and compost are classified as organic amendments which have capacity to improve soil physical, chemical, and biological properties. According to Francisco *et al*., (2017) compost amendment might content a highly complex material that organic carbon, and N chemistry vary greatly as well as micro nutrients. Under dryland management, for this reason, addition of cow manure and compost might help the soil to store the crop available water and ultimately reduce crop drought damage. With larger surface area, it is assumed that cow manure and compost may also increase the exchange of essential soil nutrient and reduce water logging as well as support crop development.

The objectives of this study was to find out the best (maximum and effisient) combination treatment of amendment from cow manure, straw compost, manure plus compost which grown with five different seed varities of peanuts.

Materials and Methods

This study was done on dryland area and located in Gampong Paud, Muara Tiga District, Pidie District, Aceh Province with coordinates between 05^{0}29'58,0"N- 95^{0}50'22,6" E, altitude± 30 m above sea level) with slope of 0 - 3%.

We measured and recorded daily temperature and rainfall sites during the study and obtainedmeans daytime temperatures reached 35,41^{0}C, in the morning 24,08 ^{0}C, and in the afternoon reached 30,4^{0}C with total rainfall during three month-growth season measured 88,5 mm. At the beginning of study, amendment chemical properties were analyzed and presented in Table 1. Soil texture was classified as silty clay at 0-20 cm depth with type of soil is Cambisol; organic carbon was around 1,04 % (Walkley and Black) and soil pH (H_2O) was 6,36.

The materials used in this research were NPK Phonska fertilizer (15:15:15) as basic fertilizer, soil amendment of cow manure, straw compost, peanut seeds, and Decis 25 EC insecticide. As indicator, we used five varieties of seeds: *Tuban*, *Hypoma* 2, *Bima*, *Kelinci,* and *Gajah*. A random complete block design (RCBD) factorial consisting of two factors and replicated three times resulted 60 plots measuring 4,0m x 1,2 m were set up. First factor of soil amendment consisting of 4 levels: without soil amendment *(S0)*, cow manure 10 tons' ha^{-1} *(S1),* straw compost 10 tons' ha $^{-1}$ *(S2),* andcow manure with 10 tons' ha $^{-1}$ + straw compost 10 tons ha $^{-1}$ *(S3)*. The second factor was varieties of peanuts consisting of 5 levels: *Tuban(V1)*, *Hypoma*2*(V2)*, *Bima(V3)*, Kelinci*(V4)*, and *Gajah(V5)*.

Table 1. Amendment chemical properties.

Amendment	Org-C	C/N	N-tot	P_2O_5-tot	K_2O-tot	pH
	%	ratio	------------------%----------------			
Cow Manure	28,52	21,77	1,31	2,69	6,69	9,40
Straw Compost	13,5	11,6	1,17	4,08	7,46	6,80

Prior to planting and harvesting, an appropriate amount of soil samples was taken for soil physical analysis such as: soil drybulk density, soil porosity, permeability, aggregate stability index, and water holding capacity at water potential-3 bar; and -15 bar. Three weeks prior to planting cow manure and straw compost were appliedaccording to ring placement method. However, NPK fertilizer was applied amounting 250 kg ha^{-1} for all treatments at planting time using ring placement method with crop spacing was 0,3 x 0,3 m. All data taken was analyzed using SPSS Statistics software ver. 17,0. One-way analysis of variance (ANOVA) was used to find out if any significant differences among treatments at $p<0,05$. Then a Least Significant Difference (LSD) test was used to compare within the means of treatments.

Results and Discussions

Soil texture class of the soil site at a depth of 0-20 cm is silty clay, and at a depth of 20-40 cm is silty clay loam. Initial soil physical properties for both depths of 0-20 cm and 20-40 cm is given in Table 3.

Table 2. Treatment combination, soil input and peanut variety used.

No	Treatment	Soil inputs	Var.
1	S0V1	0 *soil amendment*	*Tuban*
2	S0V2	0 *soil amendment*	*Hypoma* 2
3	S0V3	0 *soil amendment*	*Bima*
4	S0V4	0 *soil amendment*	Kelinci
5	S0V5	0 *soil amendment*	*Gajah*
6	S1V1	10 tonsha^{-1} manure	*Tuban*
7	S1V2	10 tonsha^{-1} manure	*Hypoma* 2
8	S1V3	10 tonsha^{-1} manure	*Bima*
9	S1V4	10 tonsha^{-1} manure	Kelinci
10	S1V5	10 tonsha^{-1} manure	*Gajah*
11	S2V1	10 tonsha^{-1} compost	*Tuban*
12	S2V2	10 tonsha^{-1} compost	*Hypoma* 2
13	S2V3	10 tonsha^{-1} compost	*Bima*
14	S2V4	10 tonsha^{-1} compost	Kelinci
15	S2V5	10 tonsha^{-1} compost	*Gajah*
16	S3V1	10 tonsha^{-1} manure + 10 tonsha^{-1} compost	*Tuban*
17	S3V2	10 tonsha^{-1} manure + 10 tonsha^{-1} compost	*Hypoma* 2
18	S3V3	10 tonsha^{-1} manure + 10 tonsha^{-1} compost	*Bima*
19	S3V4	10 tonsha^{-1} manure + 10 tonsha^{-1} compost	Kelinci
20	S3V5	10 tonsha^{-1} manure + 10 tonsha^{-1} compost	*Gajah*

Table 3. Soil physical properties at site experimentation before cultivation at two soil depths

Sites	Aggregate Stb. Index (%)		Bulk Density (Mg m^{-3})		Permeability (cm hr^{-1})	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
Site 01	46,98	50,61	1,36	1,22	36,98	50,61
Site 02	50,95	49,83	1,43	1,33	50,95	39,83
Site 03	50,65	51,38	1,24	1,21	60,65	41,38

Table 4. Soil physical properties at site experimentation before cultivation at two soil depths

Sites	Porosity (%)		Water Holding at Potential (%)			
			-3 bar		-15 bar	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
Site 01	42,14	45,56	24,2	29,6	14,7	15,9
Site 02	41,08	42,29	29,7	26,4	14,3	15,5
Site 03	46,67	48,38	29,9	28,5	16,0	16,3

Soil Physical Properties:

Results of variance analyses either individual treatment or combination show that application of amendment of cow manure or straw compost and variety of peanuts gave positive response significantly or highly significantly. Detail the influence of amendment, and of peanuts varieties on some soil properties significantly are given in Table 5. and Figure 1.

Table 5. Means of aggregate stability index, bulk density, water holding capacity (whc) at water potential -15 bar, and permeability influenced by soil amendment

Treatment	**Aggregate Stb. Index**		**Bulk density**		**WHC Potential (-15 bar)**	**Permeability**	
	0-20 cm	**20-40 cm**	**0-20 cm**	**20-40 cm**	**0-20 cm**	**0-20 cm**	**20-40 cm**
Soil Amendment			(Mg m^{-3})		%	..(cm hr^{-1})..	
$S_0$0 soil amendment	49,36a	51,96a	1,27b	1,27b	13,67a	15,95a	16,74a
$S_1$10 tonsha^{-1} manure	51,52b	53,00b	1,27b	1,24ab	14,75b	17,46ab	16,93a
$S_2$10 tonsha^{-1} compost	51,61b	53,99c	1,24ab	1,26b	14,37b	19,10b	18,42b
$S_3$10 tonsha^{-1} manure + 10 tonsha^{-1} compost	54,32c	54,98d	1,22a	1,23a	14,92b	19,72b	18,39b
LSD $_{0,05}$	0,93	0,26	0,03	0,03	0,67	1,85	1,41

Figures followed by the same letter in the same column are not significantly difference according to LSD 0,05 test

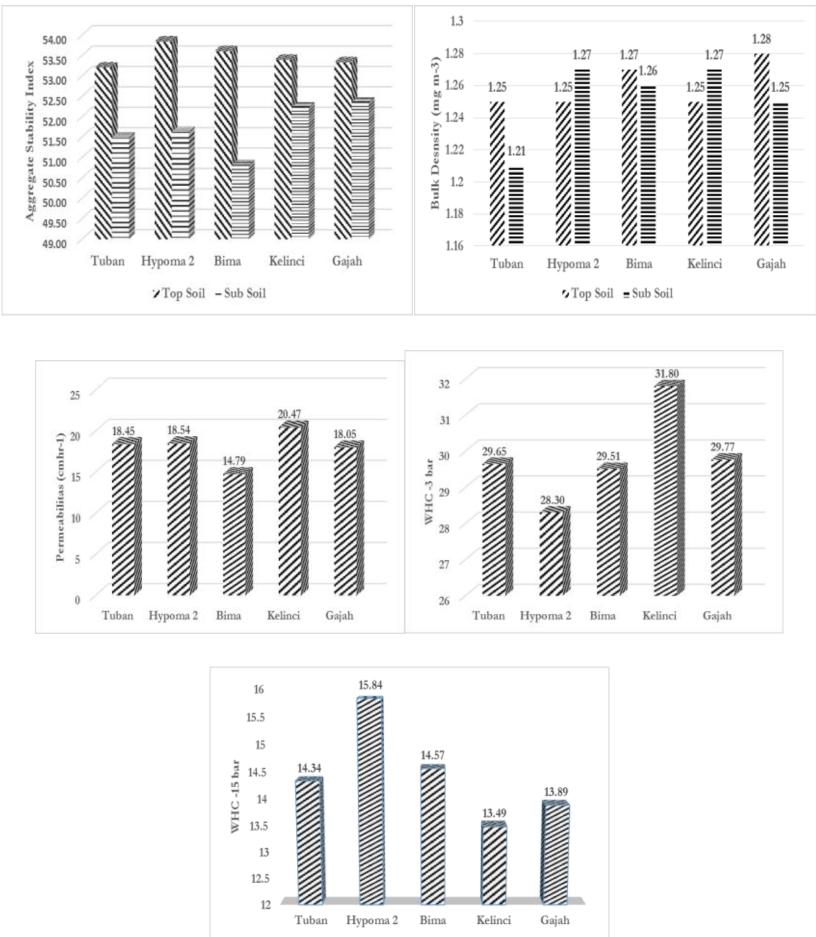

Figure 1 Means of soil physical properties affected by peanuts varieties

Table 6. Means aggregate stability index at 0-20 cm soil depth due to combinationtreatment

Soil Amendment	Variety				
	V1	V2	V3	V4	V5
$S_0$0 soil amendment	49,15a A	49,04a A	49,92a A	49,81a A	48,87a A
$S_1$10 tonsha^{-1} cow manure	49,86a A	49,29a A	50,66a A	54,81b B	52,96b B
$S_2$10 tonsha^{-1} compost	52,60b B	51,91b B	49,71a A	51,02a b A	52,82b B
$S_3$10 tonsha^{-1} cow manure + 10 tonsha^{-1} compost	54,34a b B	56,27b C	52,96a B	53,27a B	54,75a b B
LSD(SxV) $_{0,05}$			2,07		

Note: Figures followed by the same letter are not significantly difference according to $LSD_{0,05}$ test. Small letters are read horizontally, while uppercase is read vertically

Table 7. Means aggregate stability index at 20-40 cm soil depth due to combination treatment

Soil Amendment	Variety				
	V1	V2	V3	V4	V5
$S_0$0 *soil* amendment	51,70a A	51,63a A	51,85a A	52,02ab A	52,58b AB
$S_1$10 tonsha^{-1} cow manure	53,15b B	53,45b B	52,91b B	53,28b B	52,20a A
$S_2$10 tonsha^{-1} compost	53,61a B	54,26b C	54,27b C	54,08ab C	53,73a b B
$S_3$10 tonsha^{-1} cow manure + 10 tonsha^{-1} compost	54,40a bC	56,08c D	55,39b D	54,20a C	54,84b C
LSD(SxV) $_{0,05}$			0,58		

Note: Figures followed by the same letter are not significantly difference according to $LSD_{0,05}$ test. Small letters are read horizontally, while uppercase is read vertically.

The highest aggregate stability index at0-20 cm soil depth was found in in the combination treatment of 10-ton ha $^{-1}$ manure and *Kelinci* (V4) variety of 54,81 (Table 5). For soil depth at 20-40 cm, the higest aggregate stability index is found at the combination treatment between soil amendment of 10 ton ha^{-1}cow manure + 10 ton ha^{-1} compost (S3) with variety of *Hypoma* 2 (V2) was 56,08 (Table 6). This shows the organic material obtained from soil amendment and the varieties can solidify the aggregate stability index or soil aggregation. Many factors influence aggregate stability and two of them is plant diversity and biological activity (Pohl et al. 2012) and grass roots (Tisdall and Oades, 1982)

Aggregate stability is affected by the presence of soil C-organic content (Blanco-Conqui and Ruis, 2018), CEC, clay content in the soil, total pore space, and water available. The amount of organic matter as cementing agents of the particles is imperative (Hillel, 1986). Research done by Chandra and De (1982) reported that soil incorporated with manure has caused the decrease of amount soil loss due to erosion. Gilley and Risse (2000) also reported that manure application has decreased run off 2-62% and soil lost 15-65% compared without manure application.

Total Porosity

The analysis showed that no combination is found due to the combination of soil amendment and peanut varity at 20-40 cm. But it occured significantly at soil depth of 0-20 cm.

Table 8. Means soil porosity at 0-20 cm soil depth due to combination

Soil Amendment	Variety				
	V1	V2	V3	V4	V5
	.... (%)..........................				
$S_0$0 soil amendment	46,92b A	46,37b A	43,87a A	47,43b B	48,09b B
$S_1$10 tonsha^{-1} cow manure	48,64b A	50,20b B	50,86b C	43,89a A	44,42a A
$S_2$10 tonsha^{-1} compost	47,61a A	47,64a AB	47,33a B	45,69a AB	45,55a A
$S_3$10 tonsha^{-1} cow manure + 10 tonsha^{-1} compost	47,58ab A	49,27b B	47,13ab B	46,74a B	48,36ab B
LSD(SxV) $_{0,05}$			2,29		

Note: Figures followed by the same letter are not significantly difference according to $LSD_{0,05}$ test. Small letters are read horizontally, while uppercase is read vertically.

Combination treatment of varieties *Bima* (V3) with the addition of 10 tons' ha $^{-1}$ cow manure (S1) affected significantly total soil porosity (50,86 %). But there is no different from *Hypoma* 2 with 10 tons ha^{-1} (Table 8). Increased soil porosity value is apparently because the addition of organic matter and compost manure which is a source of humus that able to improve all voids in the soil structure. Lal and Shukla (2004) designated all voids in the soil can be described as soil porosity with dominant compound of porosity is gas and water. But the main influence soil porosity are bulk density and soil particle density. The decreasing soil bulk density may increase total porosity (Darusman, 1991; Hillel, 1986). However, our resultof variance analysis no combination treatment influenced soil bulk density at any soil depth

Soil Permeability

The results show that combination of varieties and soil amendment influenced highly significant on the permeability of the top soil (0-20 cm soil depth) and sub soil (20-40 cm soil depth). The means value of top and subsoil permeability can be seen in Table 9 and 10. Soil permeability is quite related to the nature of bulk density and and amount of organic matter in the soil. Our Result is coincise with the finding that soil amendment had higly significant effect on permeability at both soil depth. The highest permeability was found in the treatment of 10 tons' ha^{-1} cow manure + 10 tons of ha $^{-1}$ compost.

Table 9. Means soil permeability 0-20 cm soil depth due to combination

Soil Amendment	Variety				
	V1	V2	V3	V4	V5
	.... (cm hr^{-1})...............				
$S_0$0 soil amendment	14,74 a A	15,56 ab A	14,71 a A	19,05b A	15,69ab A
$S_1$10 tonsha^{-1} cow manure	16,50 a A	20,90 b B	15,75 a A	18,61a b A	15,56a A
$S_2$10 tonsha^{-1} compost	17,48 a A	14,49 a A	14,50 a A	26,01b B	23,03b B
$S_3$10 tonsha^{-1} cow manure + 10 ton ha^{-1} compost	25,07 b B	23,20 b B	14,18 a A	18,21a A	17,92a A
LSD(SxV) $_{0,05}$	4,14				

Note: Figures followed by the same letter are not significantly difference according to $LSD_{0,\ 05}$test. Small letters are read horizontally, while uppercase is read vertically.

Table 10. Means soil permeability 20-40 cm soil depth due to combination

Soil Amendment	Variety				
	V1	V2	V3	V4	V5
	.... (cm hr^{-1}).....................				
$S_0$0 soil amendment	18,96 b A	19,15 b B	14,19a A	13,53a A	17,87b A
$S_1$10 tonsha^{-1} cow manure	17,37 a A	18,35 a B	16,29a AB	16,73a B	15,91a A
$S_2$10 tonsha^{-1} compost	28,09 c B	13,78 a A	17,53b B	16,93a b B	15,77ab A
$S_3$10 ton ha^{-1} cow manure + 10 ton ha^{-1} compost	18,92 a A	18,83 a B	17,31a AB	18,67a B	18,22a A
LSD(SxV) $_{0,05}$	3,16				

Note: Figures followed by the same letter are not significantly difference according to $LSD_{0,05}$ test. Small letters are read horizontally, while uppercase is read vertically.

Analysis of variance resulted that combination treatments significantly influenced soil permiability at both soil depths. At 0 -20 cm soil depthcombination treatment of 10 tons ha $^{-1}$ compost (S2) with variety *Kelinci* (V4) obtained the highest permeability values compared to other treatments studied. Increased permeability values expected as a result of impairment of soil volume weight and increasing the value of soil porosity. Increased permeability is influenced by the addition of organic matter that improves soil structure also increases the total pore space the soil causing increased permeability of the soil.

At soil depth deeper, the combination treatment of 10 tons ha $^{-1}$ compost (S2) with *Tuban* (V1) resulted very significantly highest permeability value of 28,09 cm hr $^{-1}$ .Soil permeability is quite related to the nature of bulk density and amount of organic matter in the soil.

Water Holding Capacity (WHC) at Water Potential -3 and -15 bar

The results of analysis of variance of water holding capacity at water potential -3 and -15 bar at both soil depths showed only significant differences influence at 0-20 cm soil depth, but not at soil depth 20-40 cm. The means soil water holding capacity at water potential at -3 and -15 bar at soil depth 0-20 cm due to the combinationtreatment of soil amendment and varieties are presented in Table 10 and 11.

Table 11. Means of WHC at water potential -3bar due to combination (0 -20 cm)

Soil Amendment	Variety				
	V1	V2	V3	V4	V5
	.... (%).....................				
$S_0$0 *soil amendment*	30,62b A	30,10ab A	27,60a A	31,16b B	31,83b B
$S_1$10 tonsha^{-1} cow manure	32,37b A	34,41bc B	35,27c C	26,13a A	26,15a A
$S_2$10 tonsha^{-1} compost	31,35ab A	33,71b B	31,07ab B	29,43a B	29,29a B
$S_3$10 tonsha^{-1} cow manure + 10 tonsha^{-1} compost	30,65a A	32,68a AB	30,87a B	30,48a B	31,09a B
LSD(SxV) $_{0,05}$	2,85				

Note: Figures followed by the same letter are not significantly difference according to $LSD_{0,05}$ test. Small letters are read horizontally, while uppercase is read vertically.

Table 12. Means of WHC at water potential -15 bar due to combination (0 -20 cm)

Soil Amendment	Variety				
	V1	V2	V3	V4	V5
	.... (%).....................				
$S_0$0 soil amendment	14,02bc AB	13,50b A	11,02a A	14,56bc B	15,23c B
$S_1$10 tonsha^{-1} manure	15,10b B	17,31c C	17,17c C	11,69a A	12,48a A
$S_2$10 tonsha^{-1} compost	14,75b AB	17,12c C	14,47b B	12,83a A	12,69a A
$S_3$10 tonsha^{-1} manure + 10 tonsha^{-1} compost	13,55a A	15,41b B	15,60b BC	14,88ab B	15,16b B
LSD(SxV) $_{0,05}$	1,51				

Note: Figures followed by the same letter are not significantly difference according to $LSD_{0,05}$ test. Small letters are read horizontally, while uppercase is read vertically.

The highest water holding capacity at soil water potentialat -3 bar was obtained by the combination treatment of 10 tons' ha $^{-1}$ cow manure (S1) with a variety of *Bima* (V3) 35,27%. The same trend is also found at water potential -15 bar that is the highest found at the same combination treatment (17,31%).

In general, the provision of soil enhancers can increase the soil water level at potential -3 bar (field capacity). Improved soil moisture content closely related to the C-Organic content contained in soil enhancers in this case manure and compost. The higher the C-Organic in the soil causes the ability of the soil to bind water is also increasing as the organic material since the organic matter has huge surface area. Thus, clearly that the addition of organic matter will increase the moisture content in the field capacity, resulting from the increase of medium pore (*meso*) and decreased macro pore so that water retention increases and impacts on increased water availability for plant growth .

Water holding capacity at water potential -15 bar is also called the upper water storage limit of the soil and the lower extraction limit of a crop over the depth of rooting, or the lower limit of the moisture content of soil at which forces of cohesion and adhesion holding moisture in soil far exceed the pull that plant roots can exert to extract moisture from the soil (Hillel, 1986). However, the maximum soil water capacity also differs widely among soils.

Soil water holding capacity at -15 bar of water potential is also named as this is the moisture content at which plant leaves wilt permanently and do not regain turgidity even when placed in an atmosphere with a relative humidity of 100%. Similar to water content at -3 bar potential, in contrast to water content at lower limit water storage (water Potential -3 bar), this water content according to Lal and Shukla (2004) is not significantly influenced by aggregation, structural porosity, and soil organic matter content. Our results show that soil amendment had significant effect on water content at water Potential-15bar at 0-20 cm soil depth. Applying soil amendment of 10 tonsha^{-1} manure yielded significant amount of water content, except among treatments were not.

Conclusions

Overall, soil amandement improves soil physical properties. Combination amendment to variety of peanuts resulted significant effects to soil physical properties. Combination treatments mostly influenced soil physical properties at soil depth of 0 -20 cm. Addition of 10 tons ha $^{-1}$ cow manure or 10 tons ha $^{-1}$ straw compost is good enough to improve soil physical properties.

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